PERMIAN ARC VOLCANISM AND ASPECTS OF THE GENERAL GEOLOGY OF THE SKIPPERS RANGE, NW OTAGO

by

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Dedicated to Hannah

E ua, e te uaua; e mao, e te mao mao
Tihore mai i runga, tihore mai i raro
Koi mate nga tama riki a te ika nui
E kiko! E kiko e!

TABLE OF CONTENTS

Abstract vii

Acknowledgements ix

Section 1
Introduction 1-1

Section 2
Mantle Volcanics Formation 2-1

Introduction 2-1

Stratigraphy and Sedimentology 2-2

Paleontology 2-2

Description 2-3

Correlation 2-7

Interpretation 2-7

Intrusive Rocks 2-8

Mineralogy and Petrography 2-10

Olivine pseudomorphs 2-10

Clinopyroxene 2-11

Plagioclase 2-12

Chromite 2-13

Matrix Mineralogy 2-13

Metamorphism 2-14

Geochemistry 2-14

Chemical alteration 2-14

Chemistry 2-15

Fractionation history 2-20

Trace Elements 2-26

Conclusions based on geochemistry 2-30

Geochemical comparison with other Pre-Cretaceous arc-volcanics in the South Island 2-31

Summary 2-32

Section 3
Twin Lakes Trondhjemite and Associated Rocks 3-1

Introduction 3-1

Petrography of granitoid rocks 3-2

Summary 3-3

Section 4
Skippers Formation 4-1

Introduction 4-1

Content 4-1

Northern Members 4-1

Southern Members 4-4

Geochemistry 4-7

Conclusions 4-7

Section 5
Slip Hill Intrusives and Mount Webb Gneiss 5-1

Slip Hill Intrusives 5-1

Petrography 5-2

Interpretation and Correlation 5-3

Mount Webb Gneiss 5-3

Section 6
Summary and Synthesis **6-1**

Lithologic Units of the Skippers Range 6-1

Relationship of the Skippers and Mantle Volcanics Formations 6-3

The Brook Street Terrane: A critical discussion 6-4

Relationships Constrained by Intrusive Rocks of the Skippers Range and elsewhere in the Brook Street Terrane south of the Alpine Fault 6-7

References ..... **R-i**

Appendices

1 Whole rock chemistry A1-i

2 Mineral chemistry A2-i

3 Computer programs A3-i

EQUIL - A programme for the modeling of low pressure differentiation processes in natural mafic magma bodies (Nielsen 1985) A3-i

XL XRef - A programme for generating source listings of Excel™ and Lotus™ worksheets A3-xxiv

Digitizer - A programme for generating numerical coordinates from a pointing device A3-xxxii

DataConverter - A programme for re-formatting data transferred to/from other computers to the Macintosh A3-xxxv

FFT - FORTRAN File Translator A3-xxxviii

XLFRAC - A least squares mass balance program A3-xxxix

Tools - A set of small useful Excel™ macros A3-1

Phase Entry - An automated data entry form/database generator for microprobe phase data A3-lv

Whole Rock Entry - An automated data entry form/database generator for whole rock major and trace element data A3-lxv

RefCheck - A programme for listing tagged text in a document file A3-lxxv

DigitDrawII - A programme for producing PICT files of numerically defined objects A3-lxxix

Step-Scan A3-lxxxiii

Formula calculation from a mineral analysis II A3-lxxxvi

4 Crystallisation modelling discussion A4-i

5 Publications A5-i

An Early Permian fauna from the Brook Street Terrane, Skippers Range, northwest Otago.

Tholeiitic arc-ankaramites in the Permian Brook Street Terrane: possible primary melts?

Tholeiitic ankaramite volcanism in the Permian island-arc Brook Street Terrane of New Zealand.

The first *Eurydesma* fauna from New Zealand, its correlation and depositional environment.

Reconnaissance geology of Brook Street volcanic rocks adjacent to the southeastern side of the Alpine Fault, New Zealand.

6 Personal communications A6-i

LIST OF FIGURES

f indicates number of plate following page number given.

Section 1
Introduction

1-1 Geologic sketch map showing the distribution of ankaramitic basalts and derived rocks of the Brook Street Terrane and other tectonostratigraphic terranes of the South Island, New Zealand. 1-2

Section 2
Mantle Volcanics Formation

2-1 Terminology for volcaniclastic rocks used in this paper..... 2-2

2-2 Dip and dip direction of bedding planes and bearings of current directions, MVF. 2-3

2-3 Ankaramitic peperite intruding fine grained tuff with small lens of fossil debris..... 1*f*2-2

2-4 Stratigraphic column of a portion of the MVF..... 2-5

2-5 Coarse breccia at 21 m (fig. 2-4.)..... 1*f*2-6

2-6 Re-deposited bomb enclosed in tuff-breccia..... 1*f*2-6

2-7 Whole rock major element variation diagrams showing fields defined by intrusive rocks and six sedimentary rocks of the MVF for comparison. 2-6

2-8 Photomicrograph of crystal lithic tuff (58997). 2*f*2-6

2-9 Trough cross-bedded tuff below tuff-breccia with planar basal contact at 3.2 m (fig. 2-4)..... 3*f*2-6

2-10 Orientation of dikes in terms of dip and dip direction..... 2-9

2-11 Reproduction of part of aerial photograph SNC5245 G/8 (Martins Bay State Forest, alt. 12 250, 26/2/78)..... 1*f*2-8

2-12 A diagrammatic cross section of a dike during injection..... 2-10

2-13 Compositions of analysed clinopyroxenes from intrusive rocks of the MVF projected onto a portion of the pyroxene quadrilateral. 2-12

2-14 Compositions of analysed plagioclases from intrusive rocks of the MVF projected onto a portion of the plagioclase composition plane. 2-13

2-15 SiO_2:K_2O projection of MVF intrusives..... 2-15

2-16 Histogram of all analysed samples on the basis of anhydrous MgO content..... 2-16

2-17 Projection of MVF intrusives into the plane Ti:V..... 2-16

2-18a Projections of MVF intrusive rocks into planes defined by MgO and other major elements..... 2-17

2-18b Projections of MVF intrusive rocks into planes defined by MgO and analysed trace elements..... 2-18

2-19 Projection of MVF intrusive rocks into the Ni:Cr plane. 2-20

2-20 Three projections from figure 2-18a, with an EQUIL calculated liquid line of descent.... 2-22

2-21 Comparison of liquidus temperatures calculated for sample 58929.... 2-23

2-22 Comparison of phase compositions determined for sample 58929 using EQUIL and averages of the highest temperature compositions analysed in the suite.... 2-23

2-23 $MgO:Al_2O_3$ projection of sampled dike cores and margins.... 2-25

2-24 $MgO:Al_2O_3$ projection of a dike margin (58931), dike core (58932) and its analysed groundmass, along with EQUIL calculated liquid line of descent.... 2-25

2-25 Ni:Sc projection of whole rock analyses of MVF intrusives.... 2-26

2-26 MgO:Ni/Sc projection of whole rock analyses of MVF intrusives.... 2-27

2-27 Zr:Zr/other projection of whole rock analyses of MVF intrusives.... 2-27

2-28 Major and incompatible element ratios of the MVF intrusives and other suggested primary arc magmas.... 2-29

2-29 Selected hyg element abundances of the most primitive MVF intrusives, other suggested primary arc magmas and average N-type MORB.... 2-29

2-30 Mg# plotted against MgO for all analysed samples of the MVF.... 2-30

2-31 Projection of analyses of pre-Cretaceous arc volcanics of the South Island into the plane $CaO:Al_2O_3$.... 2-31

Section 4
Skippers Formation

4-1 Measurements of foliation attitudes (•) and fold axes (♦) in the Skippers Formation, northern Skippers Range.... 4-2

4-2 Large actinolite blastoporphs in a fine grained matrix.... 1*f*4-4

4-3 Varying degrees of deformation in the Skippers Formation where actinolite blastoporphs have been progressively sheared into the plane of foliation.... 2*f*4-4

4-4 Small amplitude, asymmetric similar type folds and well developed axial plane schistosity in member m_1.... 3*f*4-4

4-5 Limb of a large amplitude fold of indeterminate type in member m_1.... 4*f*4-4

4-6 The characteristic "woody" appearance of member m_2.... 5*f*4-4

4-7 Tight, asymmetric folding style typical of member m_2.... 5*f*4-4

4-8 Small scale tight symmetric and ptygmatic folding of member m_3.... 6*f*4-4

4-9 Epidote and albite filled spheroids in member m_5 which may represent an original variolitic or amygdaloidal structure.... 6*f*4-4

4-10 Oblique aerial photograph looking southwest: the Wilmot Fault with a distinctive topographic expression.... 7*f*4-4

4-11 Typical outcrop exposure of the Hokuri Intrusives member.... 7*f*4-4

4-12 Exceptionally coarse grained injection of the HI.... 1*f*4-6

4-13 Lone Stag Ultramafic member in the area of "Black Rock Bowl" (GR 043369)..... 2*f*4-6

4-14 The contact of the SPS and the LSUC..... 3*f*4-6

4-15 Mineralogical banding in Slabby Peak Schist member which may have been original sedimentary layering..... 4*f*4-6

4-16 Whole rock analyses of the five rocks of the Skippers Formation projected into the CAM composition plane..... 4-6

4-17 Comparison of porphyry textures of the Mantle Volcanics Formation and Skippers Formation..... 4*f*4-6

Section 5
Slip Hill Intrusives and Mt. Webb Gneiss

5-1 Typical textures of foliated and massive SHD..... 1*f*5-4

5-2 Contact of strongly foliated MWG and weakly foliated SHD..... 1*f*5-4

Section 6
Summary and synthesis

6-0 Schematic representations of the contact relationships and terminology used for rocks in the Eglinton Valley and Skippers Range by various workers..... 6-5

6-1 Regional distribution of Permian volcanogenic, Mesozoic intrusive and high-grade metamorphic rocks of the Skippers Range, Eglinton Valley, Dunton Range and Takitimu Mountains..... 1*f*6-8

List of Tables

Section 5
Slip Hill Intrusives and Mt. Webb Gneiss

5-1 Comparison of whole rock chemistry between Mistake Diorite and Slip Hill Diorite..... 5-3

Plates in Pocket

Tectonic map of the Skippers Range, NW Otago 1:25 000

Plate 1P Measured lithologic section, northern Skippers Range, depicting physical characteristics, intrusive relations and bulk chemistry.

Plate 2P Geologic cross sections of the Skippers Range.

Plate 3P 1:25 000 yard grid overlay for Tectonic map.

Bibliographic Reference

Ballard, Hyram R. - 1989
Permian Arc Volcanism and Aspects of the General Geology of the Skippers Range, NW Otago. Unpublished PhD thesis, 316 p., University of Otago, Dunedin, New Zealand

ABSTRACT

The Skippers Range in NW Otago is a structurally isolated block bounded by the Alpine Fault to the northwest, the Glade-Darran Fault to the west and the Hollyford Fault to the east. Within it are five intrusive and fault bounded units: The Mantle Volcanics Formation, Twin Lakes Trondhjemite, Skippers Formation, Slip Hill Intrusives and Mount Webb Gneiss. A small probably fault bounded conglomerate unit of unknown age occurs along the southwestern boundary of the Twin Lakes Trondhjemite.

The Mantle Volcanics Formation is an undeformed, moderately southwest dipping >1300 m sequence of Early Permian pyroclastic and epiclastic volcanogenic marine sediments extensively intruded by cogenetic basaltic dikes and sills. The sediments are predominantly coarse breccias and crystal lithic tuffaceous sandstones deposited by debris-flows and high-density turbidites on the flanks of an active and at least partially emergent volcanic edifice. A diverse fossil fauna from a new locality has been collected and includes the first reported occurrence of Eurydesmidae in New Zealand. The intrusive rocks span a continuous range from high MgO to high Al_2O_3 tholeiitic basalts, are characteristically clinopyroxene phyric often with crystals of quite large size and many can be classed as ankaramites. The intrusive suite is shown to be derived from high MgO, Cr and Ni primary parental melts which are represented in the dikes. These melts were emplaced into high crustal levels and erupted often with high crystal contents but without having undergone significant fractionation. The rocks of the Mantle Volcanics Formation have an incipiently developed greenschist facies mineral assemblage but have not fully equilibrated to these conditions. The Mantle Volcanics Formation represents a portion of the Brook Street Terrane, a north trending discontinuous belt of lower Permian island-arc derived volcanics and volcaniclastic sediments offset by the Alpine Fault, and a discussion of this entity is included.

To the west of and separated from the Mantle Volcanics Formation by the Wilmot Fault and the Twin Lakes Trondhjemite pluton is the Skippers Formation with a structural thickness of approximately 2 km. This is composed of essentially three protolithic types: layered ultramafics, a crustal level basic dike/sill complex and highly deformed basaltic tuffaceous sediments. Taken together, these units represent scraps of dismembered island-arc basement possibly formed in a fore-arc setting. The whole of the Skippers Formation is characterised by well equilibrated greenschist facies and actinolite (after ?clinopyroxene) blastoporphyritic textures similar to clinopyroxene porphyritic textures in the Mantle Volcanics Formation are common in all three protoliths.

Three tabular granitoid plutons, the Twin Lakes Trondhjemite between the Mantle Volcanics and Skippers Formations and two coterminous dioritic bodies, Slip Hill Diorite

and Slip Hill Granodiorite, between the Skippers Formation and schists and gneisses of the Mount Webb Gneiss are exposed in the Range. The contacts of the Twin Lakes Trondhjemite are presently faulted but there is evidence of it being intrusive into the Mantle Volcanics Formation and Skippers Formation placing a relative age constraint on their juxtaposition. The Slip Hill Intrusives are fault bounded to the east with the Skippers Formation and the Slip Hill Diorite is shown to be intrusive into the earlier deformed Mount Webb Gneiss. The Slip Hill Diorite is very similar to the Mistake Diorite, which intrudes Brook Street Terrane rocks in the Eglinton Valley, in terms of age (Early Triassic) and petrography.

The Mount Webb Gneiss was previously mapped and correlated with the Thurso Formation occurring along the coast of northern Fiordland. Some questions are raised as to the viability of this correlation.

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INTRODUCTION

The Skippers Range lies 30 km northeast of Milford Sound on the west coast of the South Island of New Zealand (see fig. 1-1). The Range is a roughly triangular block bounded by the Pyke River valley on the east, the lower Hollyford River valley with Lake McKerrow on the west and essentially the Alpine Fault to the northwest, and is some 250 square km in area. The southern half of the Range, on a line from the northern end of Lake Alabaster to Mt. Webb, is within the boundaries of Fiordland National Park with the remainder in part of the Pyke State Forest, both of which are now administered by the Department of Conservation, New Zealand.

The altitude ranges from 5 feet at the shore of Lake McKerrow to a maximum of 5 420 feet with nearly all peaks in the Range near or above 4 000 feet. The higher areas retain snow throughout the year. Geomorphology is typical of glaciated ranges; steep sided ridges and peaks, cirque basins and valleys with low angle floors that are covered with coarse talus debris at their heads and, often as not, boggy or with lakes and tarns down valley. The low angle surfaces are littered with erratics often of large size. Numerous gravity adjustment faults occur in the Range with vertical offsets from less than one to a few metres. These are usually parallel with the general structural grain and topographical ridges but in places contour around them. Many ridge crests are composed of very large, disjointed blocks, probably due to collapsing of glacially over-steepened slopes, and reliable structural attitudes were difficult to obtain. Numerous small extensional grabens occur in the northernmost part of the Range near the Alpine Fault. Often they are the site of small lakes with no surface drainage except when they overtop their banks. The grabens are probablay related to the normal sense of movement recorded along the Alpine Fault in this area. Lightning craterlets up to 1 m deep and surrounded by expulsed vegetable, soil and rock debris are common. The area above bushline is covered in tussock and associated vegetation or is exposed bare rock and snow. Thickly intergrown, often impenetrable, sub-alpine scrub vegetation occurs locally at the top of the bushline. Fauna observed on the tops were deer, chamois, skinks, rock wrens, moreporks, keas and unfortunately a ferret. In the bush and lower areas kakas, bellbirds, tuis, fantails and various other unidentified birds abound and exceptionally large, rather tasty sea-run trout are found in Lake McKerrow and the Hollyford River.

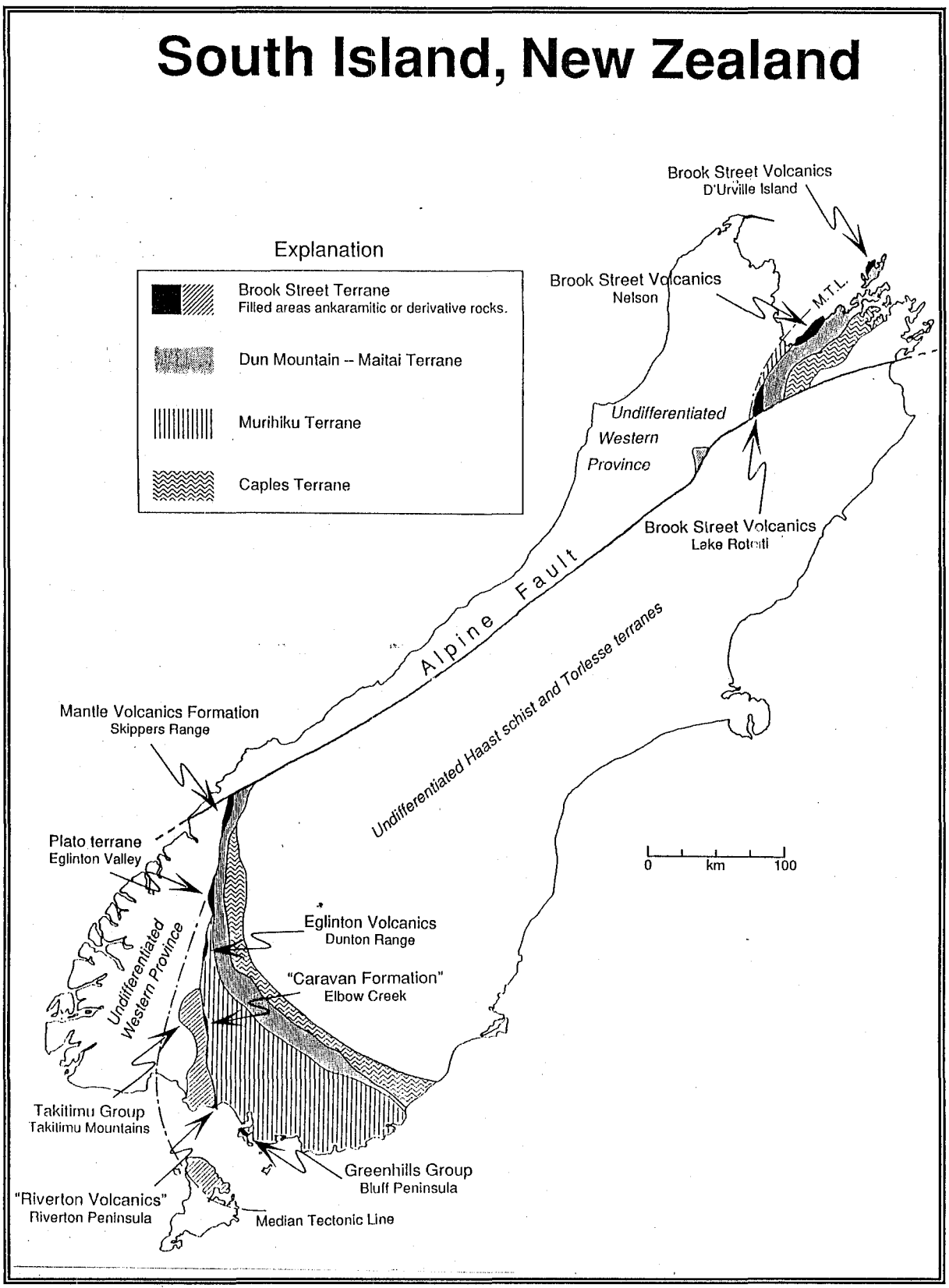

FIGURE 1-1. Geologic sketch map showing the distribution of ankaramitic basalts and derived rocks of the Brook Street Terrane (as defined in Landis and Blake (1987)) and other tectonostratigraphic terranes of the South Island, New Zealand (modified after Landis and Blake (1987)).

Field work was carried out during the summers of 1982, 1983, 1984 and 1986. Excursions averaged four weeks in duration and usually two per season between February and May. Even though this was often the time of most settled weather, 40% to 50% of time in the field was lost to unworkable conditions. During one excursion in 1984 conditions became so bad that the camp had to be abandoned and was later to be found "exploded" with rather large pieces of equipment never to be seen again. Due to the remoteness of the area helicopter transport was essential for excursions of any reasonable length and often worked in with deer recovery operations.

Mapping in the field was done on aerial photographs enlarged from film diapositives and 1:15 840 scale base maps for the published NZMS 1, 1:63 360 scale, S105 (Martins Bay) and S113 (Tutoko) sheets. Locations and contacts from the aerial photographs were transferred to a 1:15 840 compilation sheet using a zoom transfer scope in the Department of Surveying, University of Otago. This compilation was then reduced to a scale of 1:25 000 for the final map (in pocket).

This thesis began as an areal study of the Skippers Range in an attempt to map and describe the region in more detail than had previous workers (Grindley 1958; Wood 1962; Mutch 1965; Mutch and McKellar 1965; Nauman 1971), with particular emphasis on Permian volcanic rocks and their relations to adjoining crystalline rocks. Exposed in the Range are five roughly linear, northeast trending rock units: The Mantle Volcanics Formation (name introduced by Nauman 1971), Twin Lakes Trondhjemite (named here), the Skippers Formation (name introduced by Wood 1962), Slip Hill Intrusives (named here) and the Mount Webb Gneiss (named here). The Range is completely fault bounded on three sides by the Hollyford Fault to the east-southeast, the Glade-Darran Fault to the west and the Alpine Fault to the northwest. Most formations within the Range are bounded by steeply dipping to vertical faults some with obvious post-glacial vertical offset. Horizontal displacement is indeterminate due to an absence of crosscutting structures.

During initial reconnaissance my interest was drawn to the Mantle Volcanics Formation with its spectacular exposure of ankaramitic dikes intruding coarse breccias and tuffs. Much of the exposed portions of the Mantle Volcanics Formation, although having incipient development of metamorphic mineral assemblages indicative of greenschist facies metamorphism, had not equilibrated to these conditions. As such, the rocks provided an opportunity to investigate the chemical evolution and emplacement of a primitive island arc suite at a crustal level not often exposed in modern settings. Most of the field, office and laboratory work subsequently concentrated on this Formation in an attempt to determine its petrogenesis and characteristics which might provide clues to its relationship to other pre-Cretaceous arc volcanic rocks of the South Island and form a basis for comparison with modern island arcs.

The Skippers Formation was mapped and described in some detail in the southern Skippers Range south of Hokuri Creek and raised to Sub-Group status by Nauman (1973). In the present study no attempt was made to repeat this work but to verify Nauman's observations, investigate lithological continuity of the Skippers Formation between the northern and southern portions of the Range (divided by Hokuri Creek) and attempt to better understand the relationship, if any, between the Mantle Volcanics and Skippers Formations.

Formal names are here proposed for three individual granitoid plutonic bodies mapped in the Range. Two bodies making up the Slip Hill Intrusives (Slip Hill Diorite and Slip Hill Granodiorite) were previously mapped as Darran Diorite (Grindley 1958; Wood 1962; Mutch 1965; Mutch and McKellar 1965; Namuan 1971). The Twin Lakes Trondhjemite was included in the expanded definition of McKay Intrusives proposed by Namuan (1971) and this study has shown it to be intrusive into both the Mantle Volcanics and Skippers Formations.

Standard geologic analytical techniques were used in the research for this thesis including thin section and hand specimen petrography, X-ray diffraction and fluorescence, electron microprobe and computer-numerical manipulation and graphics generation. Discussions of these techniques and analytical results are presented in appropriate appendices at the end of the thesis. Descriptive terminologies are presented as required in the body of the thesis.

Sample numbers, usually given in parentheses, are Rock Catalogue reference numbers of the Department of Geology, University of Otago and held by the Curator.

Names in quotes are informal and have not been published.

MANTLE VOLCANICS FORMATION

INTRODUCTION

The name Mantle Volcanics Formation (MVF) (after Lake Mantle, Skippers Range) was given by Nauman (1971, 1973) to the volcanic and volcaniclastic rocks of the southern Skippers Range which crop out east of the "Camp Fault". It is characterised by an abundance of sub-parallel dikes of ankaramitic affinity which have invaded a continuous sequence of coarse volcanogenic sediments. The MVF is continuous and well exposed into the north of the range until its truncation by the Hollyford Fault north of Lake Wilmot.

Grindley (1958) mapped the eastern contact between the Eglinton Volcanics and Maitai Group as depositional in Alabaster Creek. My investigation of the locality revealed an outcrop of massive, green, fine grained sandstone similar to Little Ben Sandstone exposed further south in the Hollyford Valley (Landis 1980) and unlike anything observed in the MVF. The eastern contact is unexposed and lies somewhere under the Pyke River valley. It is most likely to lie closer to the western than the eastern side, inferred from the degree of shearing and veining of the MVF outcrop at the valley edge and paucity of same in the Maitai Group across the Valley. The western contact is faulted with shear zones and veining becoming increasingly abundant toward the contact. In the north, the contact is with a granitoid body most probably related to one of the MacKay intrusives of Williams (1975) and possibly the trondhjemite of Lindsay (1980). Intrusive epipheses of this granitoid can be found in the MVF near the contact and blocks of Mantle Volcanics can be found as xenoliths and rafts in the granitoid, indicating the present fault contact is subsequent upon the original intrusive discontinuity.

Faults within the MVF are discontinuous and of small offset. There is no development of penetrative deformation in either the sediments or intrusives; all rocks break with an irregular surface across grain boundaries. Local areas of intense veining and pastel colouring are probably due to local hydrothermal circulation cells active during the formation of the arc. Fractures and veins are filled with "epidosite", (a fine grained cornucopia of dubious mineralogic affinity except for the ubiquitous abundance of epidote), prehnite, quartz or rarely azurite ± malachite and disseminated sulphides.

The abundance of ankaramitic rocks in the MVF pile, the relatively small degree of chemical reconstitution and the generally primitive nature of the hypabyssal intrusives of the MVF, provide a unique opportunity for investigating the processes of the magma system operating beneath this portion of the Brook Street island-arc during generation of the MVF.

STRATIGRAPHY AND SEDIMENTOLOGY

The sedimentary rocks of the MVF form a >1300 m (base unexposed, roof lost to erosion) pile of pyroclastic and first cycle basaltic epiclastic marine sediments, gently to moderately dipping and younging southwest, which host co-genetic dikes, sills and small stocks. Sediments consist of crystal-lithic tuffs, lapilli tuffs, tuffaceous breccias and tuffaceous conglomerates with coarse to very coarse tuffaceous breccias predominating (see figure 2-1 for descriptive terminology) and no significant facies change throughout the whole of the MVF. Limestone is rare with a single 1 to 2 m band observed high in the inaccessible wall of a narrow grotto at GR 068331, and the occasional thin bed intercalated within the rest of the sediments, locally with atomodesmatinid fragments. No structures or features indicative of lava flows were observed. The flows described by Nauman (1971, 1973) could not be substantiated.

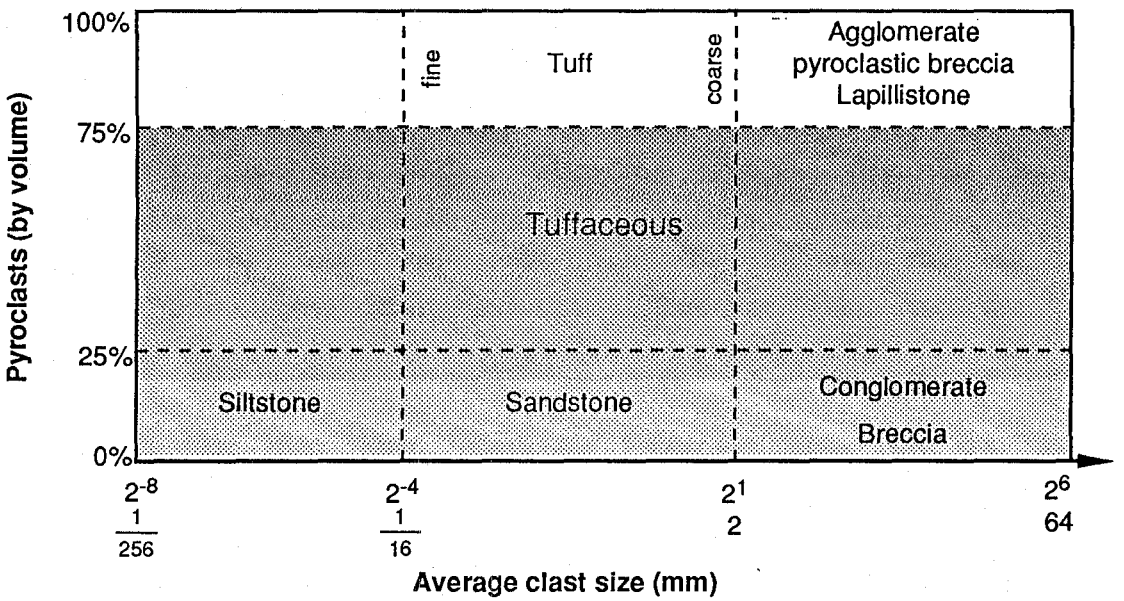

FIGURE 2-1. Terminology for volcaniclastic rocks used in this paper (after Fisher and Schminke 1986; Schmid 1981). The adjective tuffaceous is used as a prefix to indicate the size and nature of the matrix fragments.

The average dip direction is to the southwest (dip 33°; dip direction 239°; range 10°-60°;135°-280°) (fig. 2-2). Variation in attitude is locally due to rotation by small displacement faults and detachment of sediment screens between dikes, but may also represent original depositional variation. Depositional features indicate the rocks are not overturned and therefore young to the southwest.

Paleontology

Marine Permian fossils of Sakmarian age, including the bivalve *Eurydesmidae* which was previously unreported in New Zealand (Begg and Ballard 1985, 1989), were found in talus boulders up to 5 m in diameter shed from the east wall of a cirque basin at the head of

FIGURE 2-3. Ankaramitic peperite (top) intruding fine grained tuff with small lens of fossil debris (lighter band with leached moulds appearing as dark spots). Note "baked" contact below intrusion, fragmental nature of the contact, and the thin 3 to 5 cm bedsets in the tuff.

the southernmost branch of the Wilmot River (D39, GR 249304 N.Z.M.G.; fossil locality D39/f031). None were observed in place most likely due to the difficulty in recognising them in unweathered rock. Fossils generally occur concentrated at the bases of thinly bedded basaltic lithic tuff subsets (fig. 2-3) within bed sets of 1 m or greater. The fossils are preserved as recrystalised calcite in unweathered rock but are leached to external and internal moulds where weathered. Preservation is good, with fine surface features retained on many moulds. The enclosing lithology is typically very fine sand grade clinopyroxene and plagioclase crystal-lithic tuff, with isolated outsized lithic and lapilli clasts up to 20 mm in diameter. A complete faunal description is contained in Begg and Ballard (1989, Appendix 5).

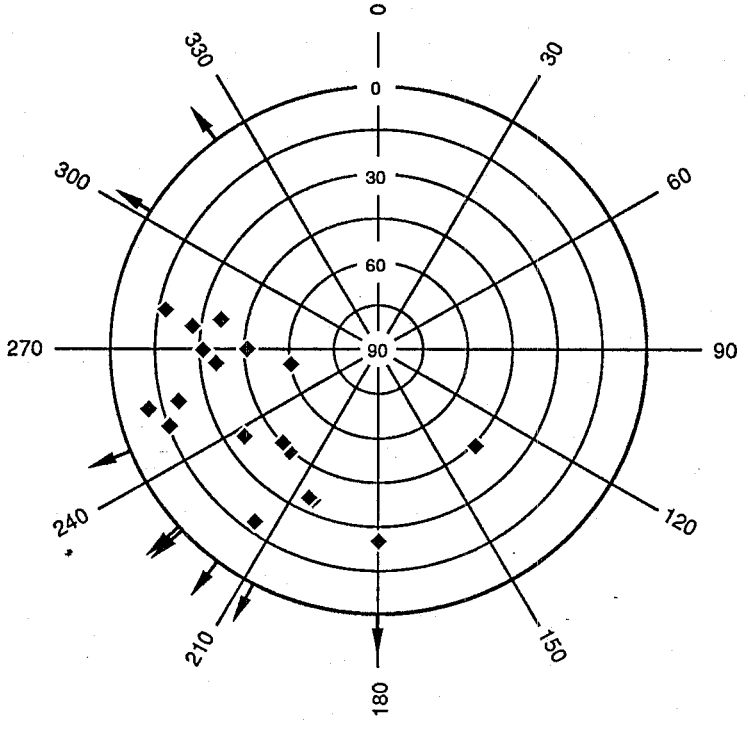

FIGURE 2-2. Dip and dip direction of bedding planes (◆) and bearings of current directions (➛), Mantle Volcanics Formation, determined in measured section depicted in figure 2-4. Current direction at 180° from average of imbricated clasts in conglomerate at 40 m; all others from trough cross-bedding in tuffs. All current directions corrected to plan by rotation about strike.

Description

A type locality of the MVF was proposed by Nauman (1971, 1973) in the area of "Loop Saddle Ridge" essentially centered on peak 4880, GR 053337. Unfortunately, this area is disrupted by a wide zone of shear associated with the western contact and is not a representative section through the MVF. A more complete, intact and undeformed section

is exposed at the head of the Wilmot River and is proposed here as a reference section. A section was measured and described at this locality (GR 093413) and is depicted in figure 2-4.

A rough correlation exists between clast size and bed thickness with coarse grained (clast size > 10 mm) epiclastic conglomerate, breccia and tuffaceous breccias predominant and forming thick beds often in excess of 1 m. They are well stratified, although individual beds may be laterally discontinuous over distances of a few tens of meters due to depositional lensing or erosional scouring. In places, water saturated tuffs have been invaded by the magma while still plastic, disrupting laminations and forming small, irregular shaped intrusions with brecciated surfaces (top of fig. 2-3). Similar features have been described elsewhere as peperites (see discussion in Cas and Wright 1987).

Breccias, tuffaceous breccias and conglomerates are poorly sorted to unsorted (sorting terminology after Jones (1967)), generally matrix supported, with weak to moderate inverse grading through individual beds and large clasts projecting into overlying well sorted finer grained beds (1, 4 and 22.5 m in fig. 2-4; fig. 2-5). Clast roundness is sub-angular to sub-rounded, though one nearly monolithologic bed was observed which consists of very well rounded boulders all of ankaramitic affinity. Conglomerate and tuffaceous breccia clasts are normally basaltic and are nearly all of the same composition as the intrusives. Some clasts are oxidised to red and purple colours. Bomb like clasts with conspicuous cooling rinds are not uncommon (fig. 2-6).

Tuffs are plagioclase and/or clinopyroxene crystal-lithic, of very fine to coarse sand size. Some also contain basaltic lapilli. Lithic clasts are basaltic and commonly vesicular with intergranular, pilotaxitic, diabasic or porphyritic textures. Clinopyroxene is the predominant phenocryst in porphyritic lithics. Tuffs and tuffaceous breccias show only minor major-element chemical deviation from fields defined by the intrusives they host (fig. 2-7). Many of the vesicular lithic clasts have retained cuspate outlines indicative of pyroclastic fragmentation (fig. 2-8). Quartz, either as a phase in lithic clasts or detrital, is entirely absent.

Common sedimentary features include normal grading, trough cross-stratification and local isolated outsized clasts and/or pebble "trains" in a finer grained matrix. Ripple laminations and mantling silts on underlying beds also occur but are less common. Cross-stratified beds range from 10 to 50 cm in thickness with steeply dipping foresets which may be traced up to 2 m laterally (fig. 2-9). These finer sediments are well sorted, ignoring outsized clasts, and often occur above coarse tuffaceous breccia units the upper portions of which fine upward abruptly over a thickness a few centimeters (e.g. fig. 2-4: 1 m, 22.5 m, and 36 m).

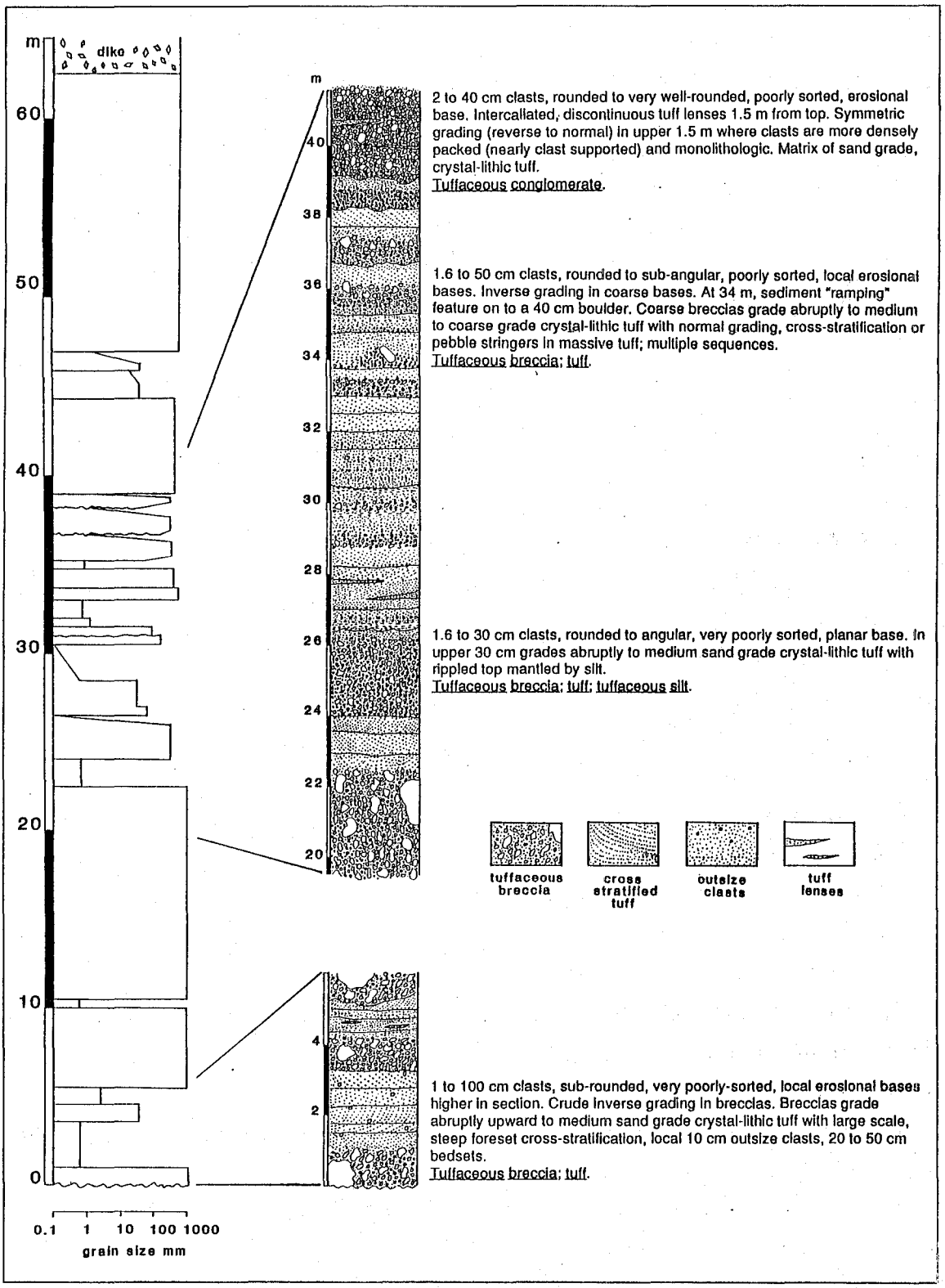

FIGURE 2-4. Stratigraphic column of a portion of the Mantle Volcanics Formation measured at GR 093413. The column on the left is schematic showing the relationship between bed thickness and clast size, note the logarithmic grain size scale. In the column on the right are enlarged sections drawn to scale and illustrating some of the salient sedimentological features of the sequence. Locations in the text refer to this column.

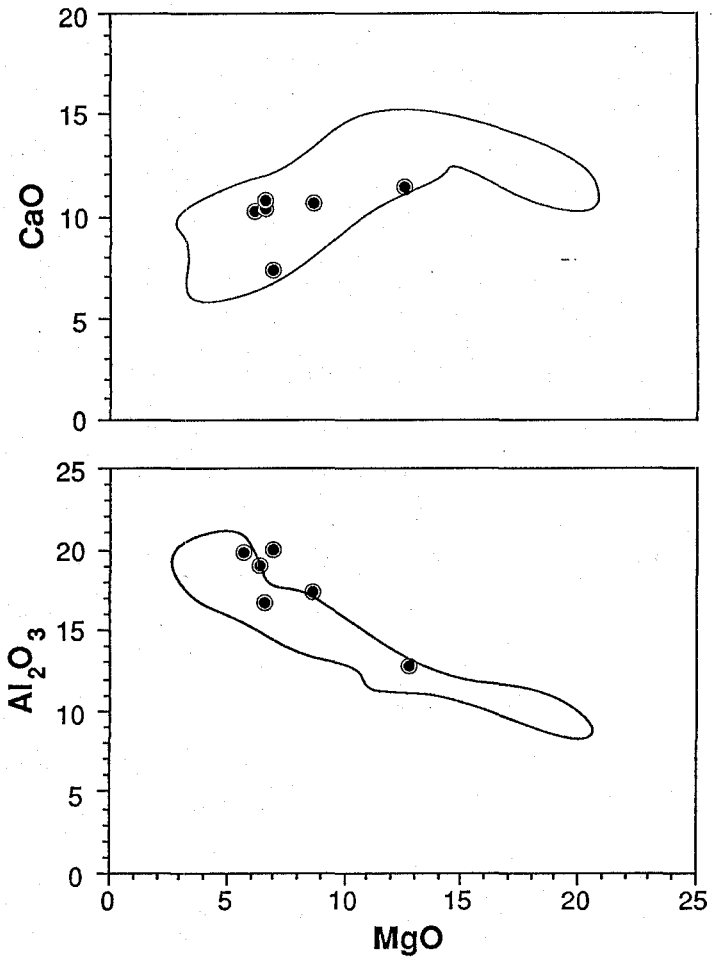

FIGURE 2-7. Whole rock major element variation diagrams showing fields defined by sixty three MVF intrusive rocks. Six sedimentary rocks of varying clast size, (58925, 58962, 58977 coarse and fine layers, 58978, 58996) are plotted for comparison.

Thick-bedded, extremely coarse tuff-breccia units with inverse grading and upward projecting clasts (e.g. fig. 2-4: 1 and 22 m) indicate a debris flow depositional mechanism (Fisher 1971; Middleton and Hampton 1973; Walker 1975). Normal grading, pebble "trains", ramping of sediment onto outsized clasts (e.g. fig. 2-4: 26.5, 29 and 34 m) and other traction features within overlying tuffaceous strata, imply deposition from high-density turbidity currents with occasional modification by residual currents to form large scale cross-stratification, ripple laminations and other features as described by Lowe (1982). No evidence was observed for deposition under shallow marine, non-marine, pelagic or hemi-pelagic conditions.

Abrupt upward fining of debris flow units to well sorted medium to coarse sand grade tuffs has also been described from the Gran Cañon Formation on Isla de Cedros, Baja California (Busby-Spera 1988). This suggests an association of a debris flow and high-density turbidity current during a single depositional event. The Gran Cañon Formation and MVF were both deposited proximal to an active volcanic vent(s) and

FIGURE 2-5. Coarse breccia at 21 m (fig. 2-4.) displaying the poor sorting, variation in clast roundness and projection of clasts at top of unit into overlying tuff (top of photograph), features common to these depositional units. Notebook (white rectangle) is 18.5 cm high

FIGURE 2-6. Re-deposited bomb enclosed in tuff-breccia. Note spindle shape and bands in cooling rind. Lens cap is 55 mm in diameter.

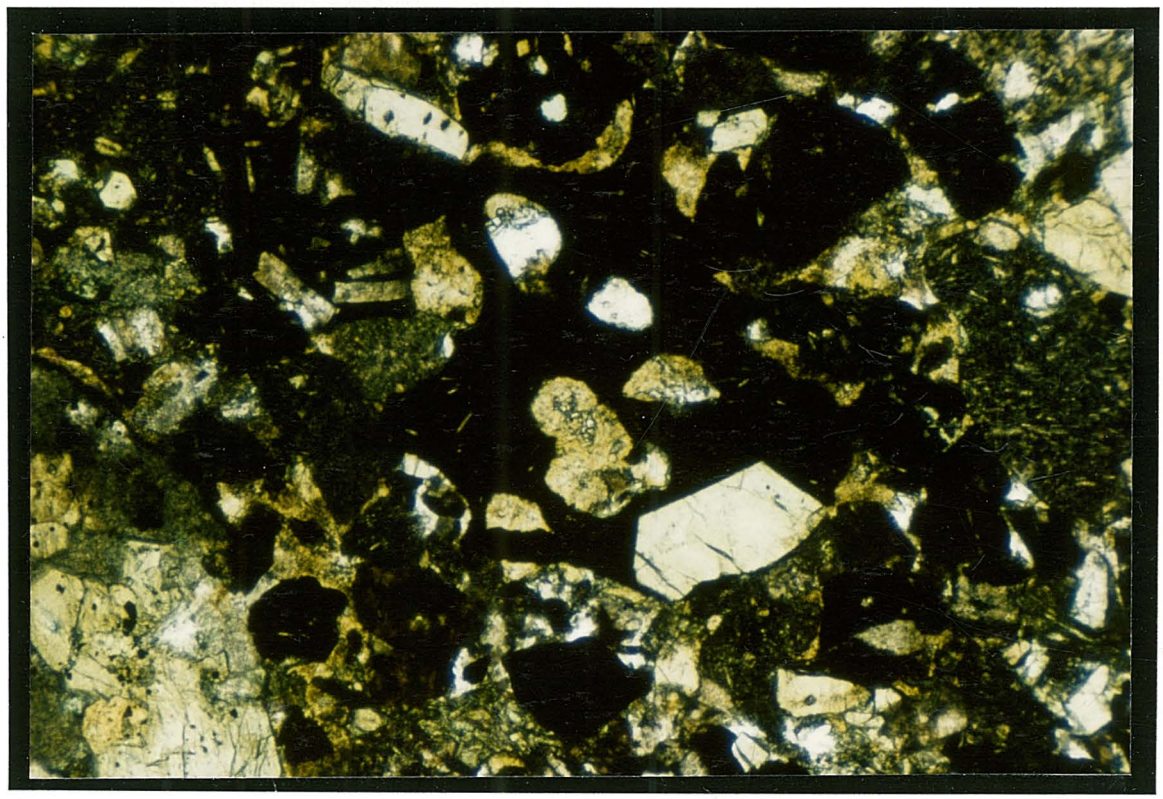

FIGURE 2-8. Photomicrograph of crystal lithic tuff (58997). A large cuspate vesicular lithic clast of pyroclastic origin occupies the centre of the photograph. The vesicles are filled with epidote and quartz and part of a large euhedral clinopyroxene crystal is at the top of the clast. Field of view is ≈6 mm.

FIGURE 2-9. Trough cross-bedded tuff below tuff-breccia with planar basal contact at 3.2 m (fig. 2-4). The foresets are quite steep and can be traced for up to 2 m.

seismic activity may have triggered marine and/or sub-aerial landslides which developed into debris flow/high-density turbidity current depositional pairs.

Correlation

The MVF can be correlated with the Gondor Formation of the Plato terrane of Williams (1975) on the basis of similarity of enclosing lithologies, and also with the Wesney Siltstone of Landis and Waterhouse (1966) due particularly to the existence of conspicuous, abundant "augite porphyrite" (Grindley 1958) or ankaramite dikes intruding these formations. The Takitimu Group contains no ankaramite related intrusive or clastic rocks. A fault bounded volcanic suite termed the "Caravan Formation" separated from the main Takitimu sequence by an in-faulted sliver of Murihiku Supergroup rock and bounded on the east by the Productus Creek Group does however contain ankaramitic rocks (C.A. Landis pers. comm. 1989). West of the Alpine Fault, the Kaka Formation in the Nelson area is the most likely correlative to the MVF based on the abundance of augite rich tuffs and breccias. The augite crystals are up to 25 mm in length and occur as grains in the tuffs and as phenocrysts in the breccia fragments (Bruce 1962; Johnston 1981). Sivell and Rankin (1983) report a 2400 m thick sequence of marine basaltic pyroclastic rocks containing abundant clinopyroxene crystal fragments intruded by ankaramitic dikes and sills on D'Urville Island which are also probably correlative to the MVF.

Preliminary paleomagnetic data from the MVF indicate generation at 47° latitude, and if in the southern hemisphere, during a time of normal magnetic polarity (B. Luyendyk, pers. comm. 1986). The Permian is for the most part a reversed period with the exception of three short normal events, two of which are in the Sakmarian (Irving and Pullaiah 1976). Data from the Takitimu Group indicate a S 27.8° paleolatitude with a reversed polarity (Haston et al. 1987). This discrepancy in paleomagnetic inclination and polarity between the MVF and the middle of the Takitimu Group indicates deposition in significantly different global positions during, at least in part, different times.

Interpretation

The whole of the MVF sedimentary pile represents a moderate to deep water proximal facies deposited on the submarine flanks of an active island volcano which was, at least in part, emergent. The finer detritus records both pyroclastic and epiclastic fragmentation. Monomict boulder breccias and conglomerates were probably derived from epiclastic processes and indicate at least some sub-aerial extrusive outpourings of ankaramitic and basaltic lavas. There is no continental detrital component in the sediments. All detritus has been derived from the extrusive equivalents of lithologies represented by the intrusives into the pile.

The co-directional nature of the dip directions, paleo-current bearings and younging direction imply that the pile has experienced only moderate tilting during its tectonic

history. In striking contrast are the near vertical to locally overturned 14 km thick Takitimu Group strata of the central Takitimu Mountains (Houghton 1977) and the Plato terrane sediments which generally dip eastward 60° to 80° with local overturning (Williams 1975). The Takitimu Group and Plato terrane young to the east, whereas the MVF young to the southwest and is nowhere overturned. The MVF has thus escaped significant deformation other than undetectable vertical axis rotations during amalgamation to the Gondwana continental margin and in subsequent tectonic re-positioning. If the MVF, the Gondor Formation and Wesney Siltstone of the Plato terrane were amalgamated onto the Gondwanaland margin in the same episode, considering the Plato terrane's greater extent of deformation, the implication is that the more extreme deformation of the Plato is post amalgamation.

INTRUSIVE ROCKS

The most distinctive petrographic feature of the intrusive rocks of the MVF is the abundance of phenocrystic and megacrystic basalts. These are often so rich in clinopyroxene relative to other phases that they can be descriptively characterised as ankaramites. The name ankaramite was first used by Lacroix to describe a rock which "...occurs as a dike, and is olivine-bearing and melanocratic, rich in pyroxenes up to 1 cm in diameter, and somewhat fewer and smaller olivines." (Johannsen 1937). The term shall be used here to describe melanocratic rocks in which conspicuously large clinopyroxenes are the dominant megascopic phenocryst phase.

MVF intrusives occur predominantly as dikes with subordinate sills and small stocks. Dikes range in thickness from 17 cm to 3.88 m and average 1.36 m. Dips range from 45° to 90° with an average of 74° and dip directions range from 122° to 330° and average 266° (see figure 2-10). Based on measured lithologic sections, one of which is shown in Plate 1P (in pocket), the intrusive rocks make up to 35% of the total rock exposure (linear measure perpendicular to average dike strike). Locally emplacement had taken place before the sediments had fully de-watered, forming irregular, fragmented intrusions somewhat resembling small pillow like structures which have been termed peperites (Cas and Wright 1987). Some of the smaller dikes are quite irregular in shape forming sinuous intrusions. The larger dikes are very planar with parallel margins and only a few pinch and swell. Cross-cutting relationships are rare and do not have any significant relationship to degree of magmatic evolution of the dikes. Xenoliths occur only in two large, coarse grained olivine gabbro dikes which are quite obvious both in air photography (see figure 2-11) and on the ground. A number of these xenoliths were sampled using a core drill and are predominantly ankaramites or basalts similar to other dikes with a few being

FIGURE 2-11. Reproduction of part of aerial photograph SNC5245 G/8 (Martins Bay State Forest, alt. 12 250, 26/2/78). The small tarn near the centre of the photograph is located at GR 086420 and it about 60 m across. The dikes create a pervasive linear texture and can be seen as light and dark coloured lineaments oriented NE-SW. The fainter cross cutting lineations oriented nearly E-W are formed by the bedding of the enclosing sediments. The large gabbro dikes can be seen in the area north of the tarn between it and the snow patch to the upper left.

coarse grained pyroxenites and peridotites. A few dikes show evidence of multiple injection (e.g. 58969) but no "sheeting" of dikes was observed.

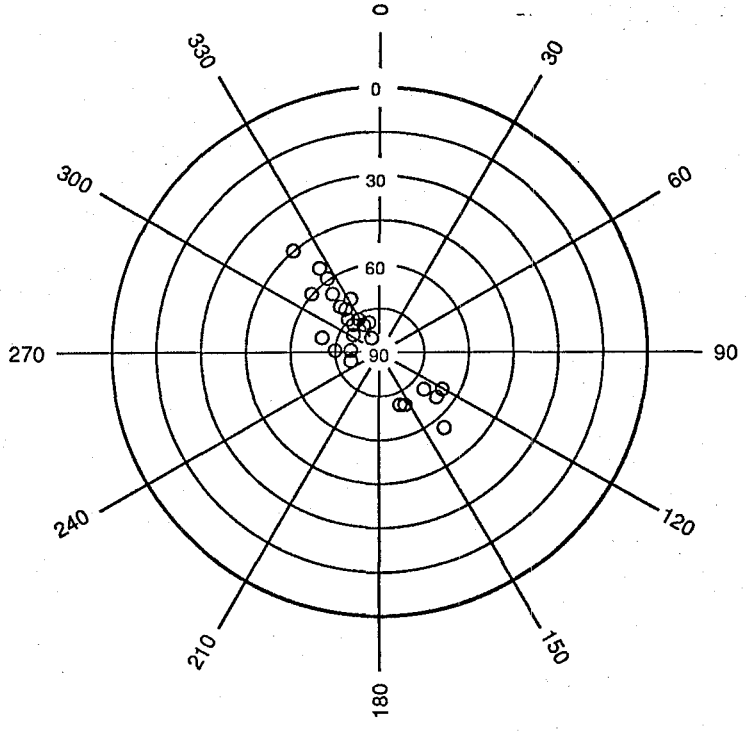

FIGURE 2-10. Orientation of dikes in terms of dip and dip direction. Eleven dikes plot at the center of the diagram but are not shown for clarity.

Many of the dikes have fine grained marginal zones of varying thickness with phenocrysts both smaller in number and size, and generally richer in plagioclase than the coarser grained, mafic phenocryst rich core zones. This gradation commonly occurs over a small distance and shows no sign of being of multiple intrusive origin. Flow segregation is ruled out as there are never any large core-like phenocrysts trapped in the extreme margins where freezing of the first intruded liquid would have taken place (see figure 2-12).

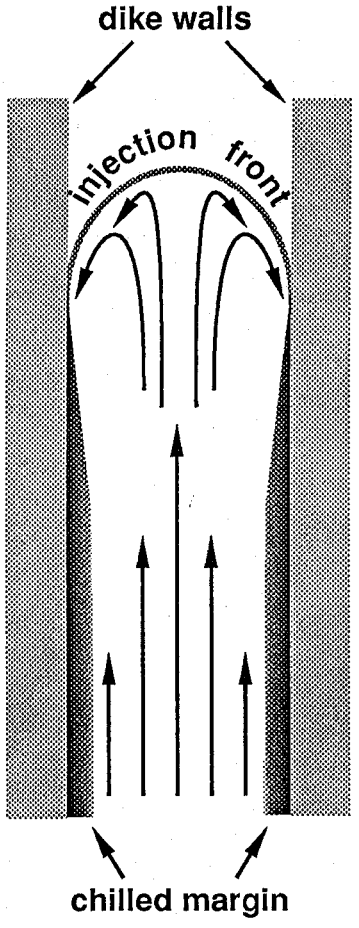

FIGURE 2-12. A diagrammatic cross section of a dike during injection with lengths of flow lines proportional to flow velocity. Note that when the faster moving core material reaches the flow (injection) front it must move laterally and produces a region of back-flow proportional to the velocity and viscosity of the the material. In any fluid injection system where freezing takes place at the margins of the conduit, it is the core material that would be first to come in contact with the conduit walls before they could become heated by the fluid. Continual freezing to the margins would build up a chilled zone, which through loss of heat to the walls and insulating the conduit, would effectively reduce the temperature gradient across the boundary. At this point if flow were interrupted and a non-homogeneous fluid allowed to freeze, the particle gradation produced by the differential flow of the fluid would be preserved inboard of a chilled margin containing at least some of the core region particles frozen to the walls.

Mineralogy and Petrography

In hand specimen the MVF intrusives vary in colour from dark grey to greyish black on fresh surfaces and tend light to medium bluish greys to dark grey on weathered surfaces with more olivine rich varieties dark reddish brown. Nearly all are porphyritic with phenocrysts ranging in size from less than 1 mm to 2 cm and in content from less than 2% to some in excess of 50%. The phenocrysts are olivine (pseudomorphed), clinopyroxene and plagioclase (altered). The rocks are in general hard and coherent with little veining or fractures. Phenocrysts of plagioclase and clinopyroxene often stand in relief on weathered surfaces. Some are amygdaloidal, most likely due to original vesicularity, with the amygdales filled with calcite ± quartz ± epidote. General texture is phenocrystic to megacrystic intergranular with some tending to intersertal.

Olivine pseudomorphs

These are commonly idiomorphic to subidiomorphic and composed of aggregates of various mineral assemblages such as: quartz + chlorite + fibrous amphibole ± calcite ± epidote ± magnetite; quartz + talc + calcite + chlorite; calcite + talc + chlorite; fibrous amphibole + quartz + chlorite. Many pseudomorphs also have small garnet crystals. "Interfacial" angles of an idiomorphic pseudomorph in sample 59004 were measured:

(021)^(02$\bar{1}$)=99.0° and (021)^(010)=40.7°. The actual values for olivine are 99.07° and 40.47° respectively, ruling out the possibility of the pseudomorphs having been originally orthopyroxene. The fibrous amphibole is actinolite (length slow, pleochroic light green to dark green, γ^c≈20°). In the talc + magnetite ± chlorite ± calcite pseudomorphs, magnetite occurs as dusty coatings or aggregates of euhedral crystals in what may have originally been cleavage planes or cracks. Many of the pseudomorphs also contain variously sized euhedral to subhedral magnesio-chromite inclusions.

No relict olivine was found in any of the samples.

Clinopyroxene

Clinopyroxene phenocrysts and megacrysts are most conspicuous and generally idiomorphic to subidiomorphic. Size of these phenocrysts ranges from less than 1 mm to greater than 2 cm. Pleochroism, when shown, is faint pink to pale green; $2V^{+}$≈48° to 60° and γ^c≈42°. Some crystals are broken with the individual fragments identifiable and not far separated indicating intratelluric fragmentation. Small patches of alteration, some showing crystal outlines, contain phases identical to those found in olivine pseudomorphs. These are interpreted as having been olivine inclusions in the clinopyroxene. Euhedral to subhedral magnetite inclusions are present in some grains.

Large crystals are often zoned with large optically continuous cores surrounded by zones the bandwidth of which decreases outward to a final tecoblastic rim containing inclusions of matrix crystals. Chemically the zoning from core to rim is along an augite exchange vector approximated by the formula $Ca_{-0.3}Na_{0.1}Mg_{-1}FeTi_{0.1}Al_{0.6}Si_{-0.3}$ with minor elements Mn increasing and Cr decreasing. Composition of the clinopyroxenes ranges from diopside or endiopside to augite with cores of megacrysts and phenocrysts tending to be diopside rich and rims and groundmass grains augite (figure 2-13). Clinopyroxene analyses may be found in Appendix 2. Many of the analysed phyric cores have measurable and significant Cr_2O_3 content and can be classed as Cr-diopsides. All clinopyroxenes are low in Na_2O and TiO_2 (both <0.5%) and phenocryst cores generally have less than 3% Al_2O_3. These compositions are very similar to those produced by Grove and Bryan (1983) in an experimental study of crystallisation of pyroxene phyric MORB at one atmosphere. This suggests that the MVF clinopyroxenes crystallised at low pressure within the crust.

Clinopyroxenes of similar composition are found in other arc-picrites and -ankaramites of both modern arcs such as New Georgia, Solomon Islands (Stanton and Bell 1969; Cox and Bell 1972; Ramsay et al. 1984); Lombok, Sunda arc (Foden 1983); Merelava, Vanuatu (Barsdell 1988); East Island, Crozet Archipelago (Gunn et al. 1970); in inferred arc remnants like the Plato Terrane, New Zealand (Williams 1975); and Choyal Terrane, Cedros Island, Baja California, Mexico (Kimbrough 1982) and from ultramafic inclusions in andesite, Mt. Moffett volcano, Adak Island, Aleutian arc (Conrad and Kay 1984).

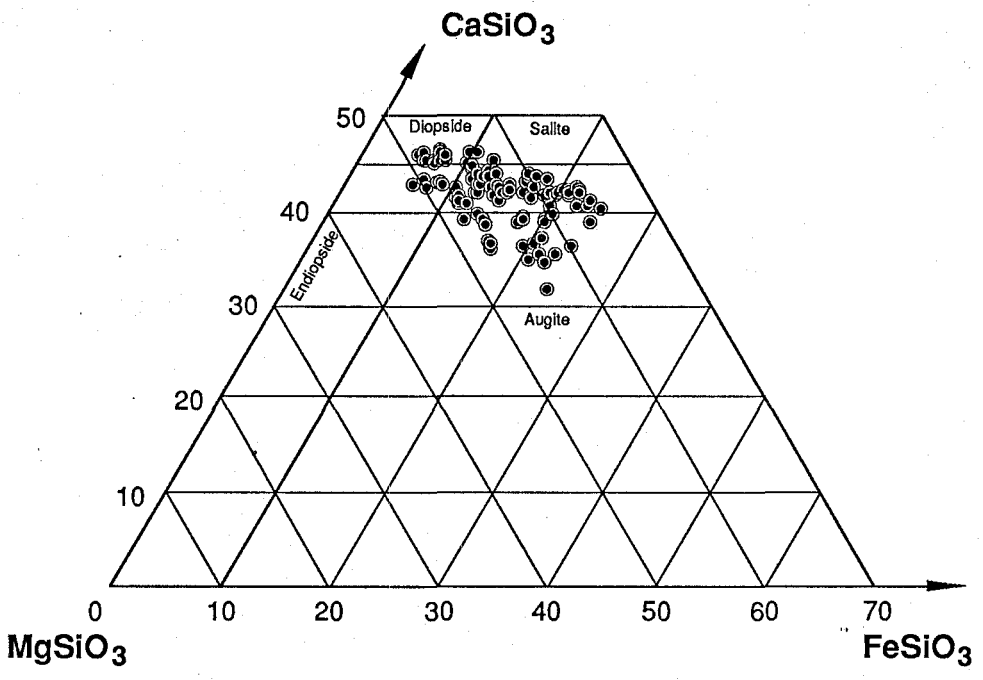

FIGURE 2-13. Compositions of analysed clinopyroxenes from intrusive rocks of the Mantle Volcanics Formation projected onto a portion of the pyroxene quadrilateral. The data includes cores and margins of zoned megacrysts and phenocrysts and groundmass compositions.

Plagioclase

Plagioclase occurs as grains 1 to 3 mm and is often incompletely altered to albite + quartz + muscovite + epidote ± prehnite. The alteration often displays "ghost" zoning which follows inferred original compositional zones often still visible at the rims. The small intrusion (28 m plate 1P in pocket; sample 58935) has exceptionally pristine plagioclase phenocrysts which appear "dusty" due to hematite inclusions. Phenocrysts are idiomorphic to subidiomorphic except where in growth contact with other phenocrysts.

Phenocrysts occur predominantly as single crystals and less commonly in glomeroporphyritic clots some monomineralic and others with olivine and plagioclase. The glomeroporphs are rarely hypidiomorphic, and appear to be individual magmatic crystals which have come together at an early stage and become intergrown.

Plagioclase analyses are presented in Appendix 2. Compositionally, the plagioclase microlites range from An_{45} to An_{83} (oligoclase to bytownite, figure 2-14) and altered phenocrysts must have been more anorthite rich than the coexisting groundmass feldspar. Plagioclase of these compositions would have relatively high liquidus temperatures, on the order of 1450°-1550°C in the binary system, though the actual values would be lower than this in a complex basalt system.

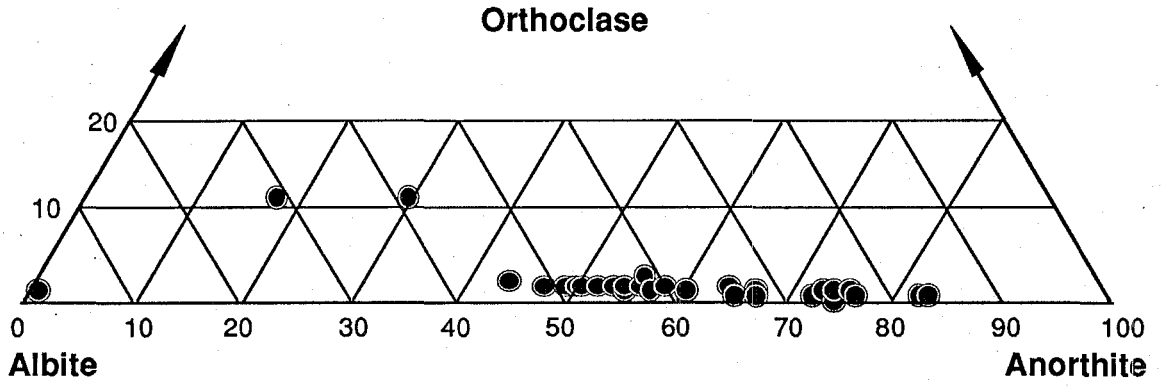

FIGURE 2-14. Compositions of analysed plagioclases from intrusive rocks of the Mantle Volcanics Formation projected onto a portion of the plagioclase composition plane. The two most albitic analyses are from an altered phenocryst and the next more anorthitic from an altered microlite. The high orthoclase components two of these analyses are from muscovite contamination.

Chromite

Chromite analyses are presented in Appendix 2. Although chromite doesn't exist as a true phenocryst phase, it is discussed here as it was the first crystallising phase. This is evidenced by its preservation only as well formed inclusions in olivine (now pseudomorphed) which shielded it from further reaction with melt. All groundmass spinels are later crystallising magnetite. Any chromite which was not insulated from the melt probably was resorbed due to peritectic reaction between Cr-spinel and Cr-diopside (Irvine 1967).

The chromites are of a high chrome, low alumina variety ($^{Cr}/_{Cr+Al}$ = 0.73 to 0.79) similar to those found in stratiform ultramafic intrusions (Irvine 1967) which are thought to represent low pressure differentiation of tholeiitic magma (Carmichael et al. 1974). In these types of intrusions, chromite occurring as inclusions in olivine is unknown but instead tends to occur as anhedral intergrowths between silicates (Dick 1977). For these reasons Nye and Reid (1986) suggested that the olivine phenocrysts in an arc picrite from Okmok Volcano, Central Aleutians were magmatic and not inherited xenocrysts. The same deduction can be made in the case of the MVF and that the later clinopyroxene and plagioclase phenocrysts must also be of low pressure magmatic origin.

Matrix Mineralogy

Groundmass phases are olivine (pseudomorphed), clinopyroxene, plagioclase and magnetite. Olivine is of the same occurrence as above but of smaller size and subidiomorphic to xenomorphic. Clinopyroxene is similar to the phenocrysts but of smaller size, subidiomorphic to xenomorphic, without inclusions and compositionally similar to the rims of the phenocrysts and megacrysts (see Appendix 2). Plagioclase microlites tend to be less altered than the phenocrysts and compositionally range from An_{45} to An_{83} (figure 2-14). Magnetite occurs as idiomorphic to subidiomorphic grains 0.06 to 0.10 mm.

Metamorphism

Metamorphic phases occur almost exclusively as alterations to primary minerals and are summarised in the sections above.

Prehnite occurs as an alteration phase of plagioclase and rarely as small veinlets. Pumpellyite was not observed in any of the rocks collected for this thesis but was reported by Nauman (1971). Upon further investigation, the sample locations where pumpellyite was reported were found to be either in or near the contacts of the MVF where deformation and alteration are extensive and not representative of the MVF as a whole.

Away from the contacts there is no pervasive or even incipient development of a metamorphic fabric within the MVF. Mineralogically, the distinguishing phases are prehnite + albite + quartz + epidote ± actinolite, actinolite being developed as an alteration of clinopyroxene in the more altered samples placing the MVF in a sub-greenschist facies metamorphic grade, probably prehnite -pumpellyite.

Geochemistry

Sample preparation procedures, raw analyses, anhydrous and norm re-calculations are given in Appendix 1. FeO and Fe_2O_3 have been calculated as $Fe^{3+}/Fe^{2+}=0.15$ for anhydrous and norm calculations which approximates inferred magmatic conditions (Bryan et al. 1981; Geist et al. 1986) All comparative whole rock analyses have been corrected to this iron ratio and all plotted samples and quoted values are anhydrous. The re-casting of analyses to anhydrous values reduces effective differences between samples and suites caused by alteration effects and errors in determination of volatile content.

Chemical alteration

Considering the age, metamorphic grade and emplacement environment of the intrusive rocks of the MVF, it is important to assess the potential disruption of chemical signatures by post-emplacement hydrothermal alteration, weathering and low grade metamorphism. All of the dikes have thin, very fine grained chill margins which may have provided some protection from initial component exchange with enclosing sediment during cooling. Penetrative deformation, which would provide a pathway for fluid exchange, is non-existent in the core of the MVF outcrop area. Areas of veining and in-filled fractures are localised within the MVF and about the faulted contacts and these areas were not sampled for geochemical analysis. The rocks show incomplete conversion to a greenschist facies phase assemblage indicating metamorphism was relatively "dry" without a pervasive fluid phase. As such, recrystallisation and equilibration was inhibited.

As discussed in the section " Mineralogy and Petrography", plagioclase microlites have high anorthite contents and are often quite pristine or with minor alteration (see Appendix 2). Although olivine and plagioclase phenocrysts have been extensively altered, the compositions of replacement phases are in keeping with the chemical redistribution being on a small (thin section to hand specimen) scale. Some of the more mobile

components such as K and Rb, should retain their initial ratios though absolute values may be disturbed. Major elements show reasonably good inter-element correlations, suggesting they are near to their original values, and most trace elements have been shown to be essentially immobile under most low grade alteration processes (Levi et al. 1982; Humphris and Thompson 1978; Pearce 1975).

Chemistry

The hypabyssal rocks sampled comprise a calc-alkaline transitional suite from low-K tholeiites to high-K basaltic andesites with a few samples just in the field of the Shoshonitic Series (fig. 2-15). The suite spans the range from high-Mg (18% to 20% MgO) to high-Al (20% Al_2O_3) basalts and can be divided into three categories based on MgO content: 2 to 8%, 8 to 15% and 18 to 21% (fig. 2-16). Nearly all of the samples fall well within the fields determined by Shervais (1982) for arc associated rocks, and out of the fields of back-arc basin basalts (BAB) and mid-ocean ridge basalts (MORB) (fig. 2-17). All of the variation within the suite can be accounted for by varying degrees of crystallisation and crystal segregation processes operating on a parental magma of primitive composition.

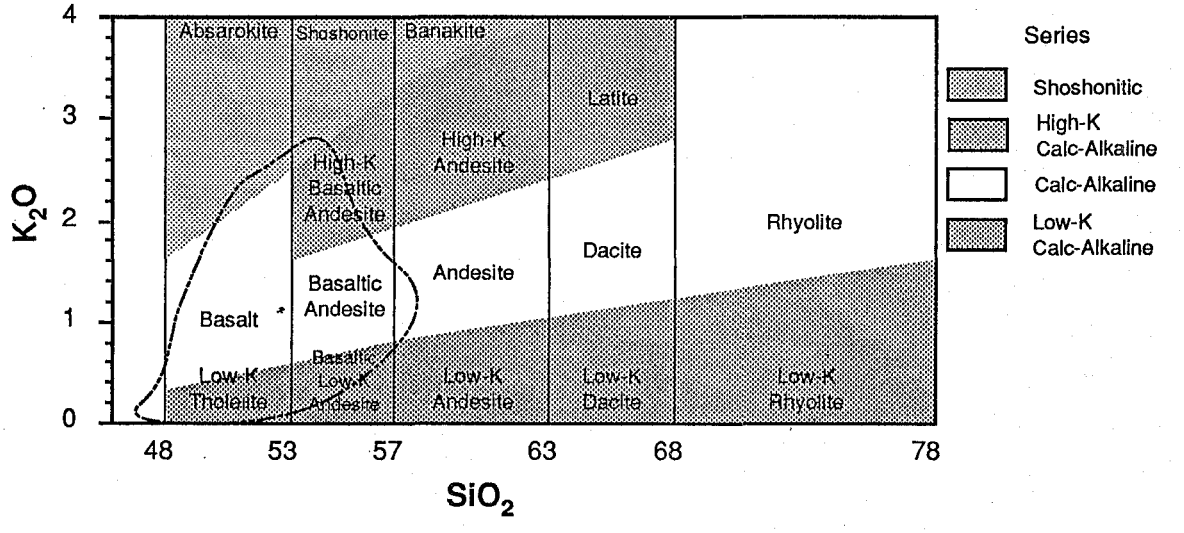

FIGURE 2-15. SiO_2:K_2O projection with enclosing field of MVF intrusives and shaded areas delimiting classification scheme for island arc rocks (after Basaltic Volcanism Study Project 1981). The values plotted are re-calculated anhydrous. Maximum error for K_2O is 0.09 weight percent (see Appendix 1).

From petrography the inferred phenocryst crystallisation sequence is: chrome spinel ± olivine; olivine + clinopyroxene, olivine + clinopyroxene + plagioclase. Plagioclase phenocrysts occur in varying abundance in even the most mafic samples, indicating crystallisation on the olivine-clinopyroxene-plagioclase cotectic before the onset of intratelluric crystallisation and subsequent emplacement.

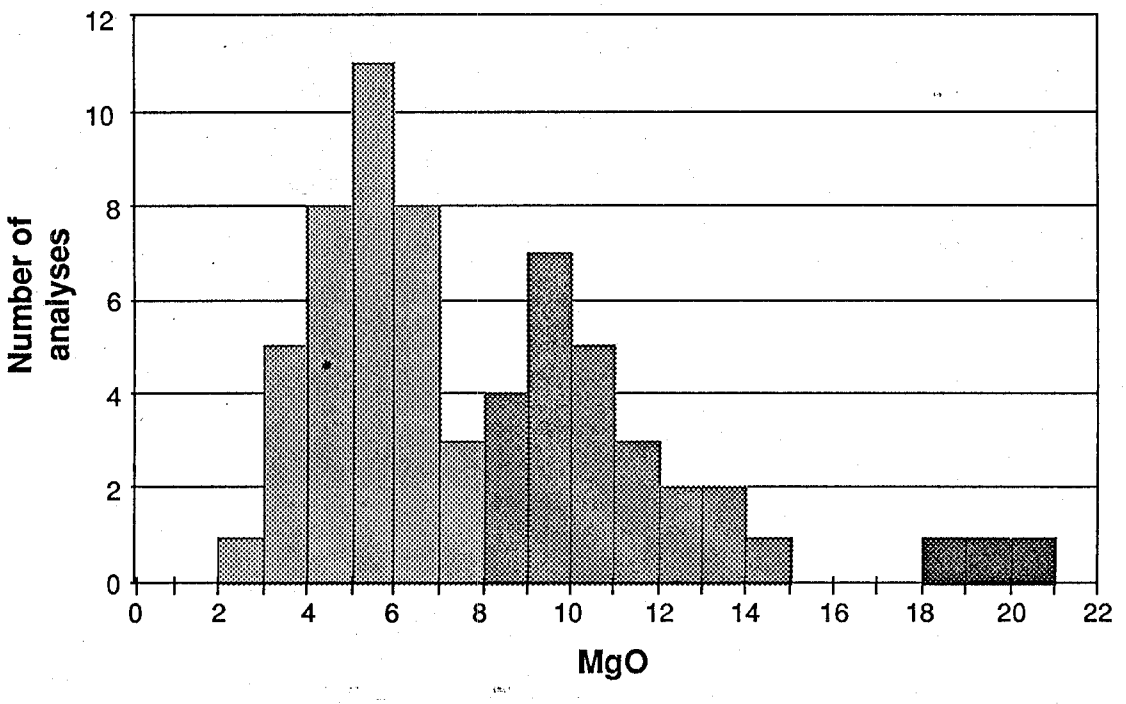

FIGURE 2-16. Histogram of all analysed samples on the basis of anhydrous MgO content. Note the three distinct groupings at 18% to 21%, 8% to 15% and 2% to 8%.

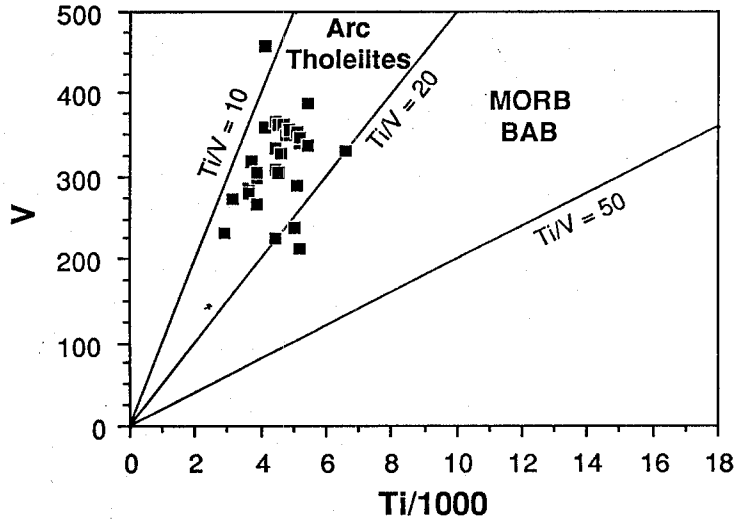

FIGURE 2-17. Projection of MVF intrusives into the plane Ti:V with lines of equal ratio. Shervais (1982) has shown that arc tholeiites and ankaramites plot on or near a chondritic trend (Ti/V=10) and have Ti/V ratios ≤20 whereas MORB are confined almost entirely to ratios between 20 and 50 and back-arc basin basalts (BAB) also fall mainly between ratios of 20 to 50 with some less than 20. Data from Appendix 1, units of ppm.

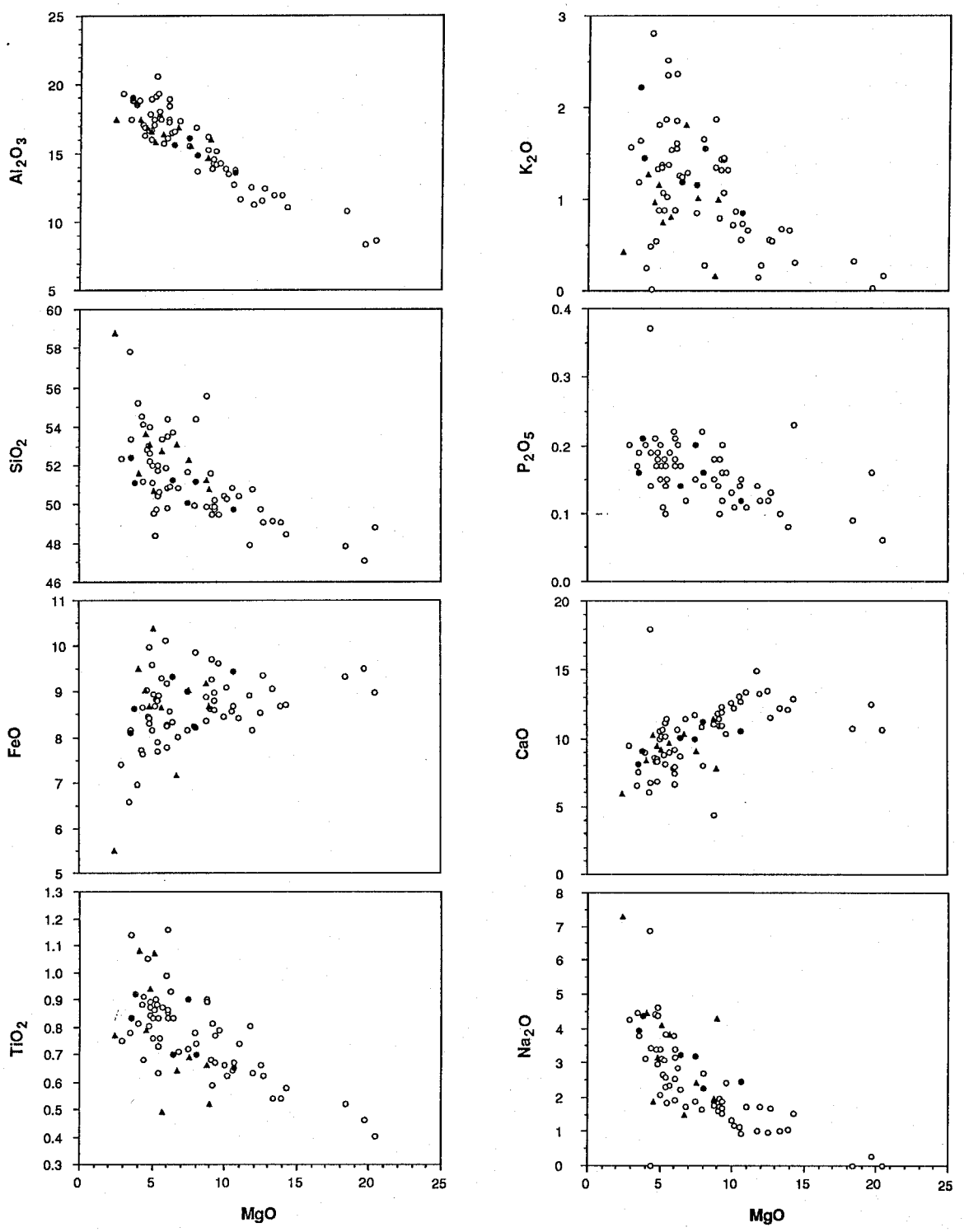

FIGURE 2-18a. Projections of Mantle Volcanics Formation intrusive rocks into planes defined by MgO and other major elements. ○ = dike cores, ● = dike margins, ▲ = groundmass.

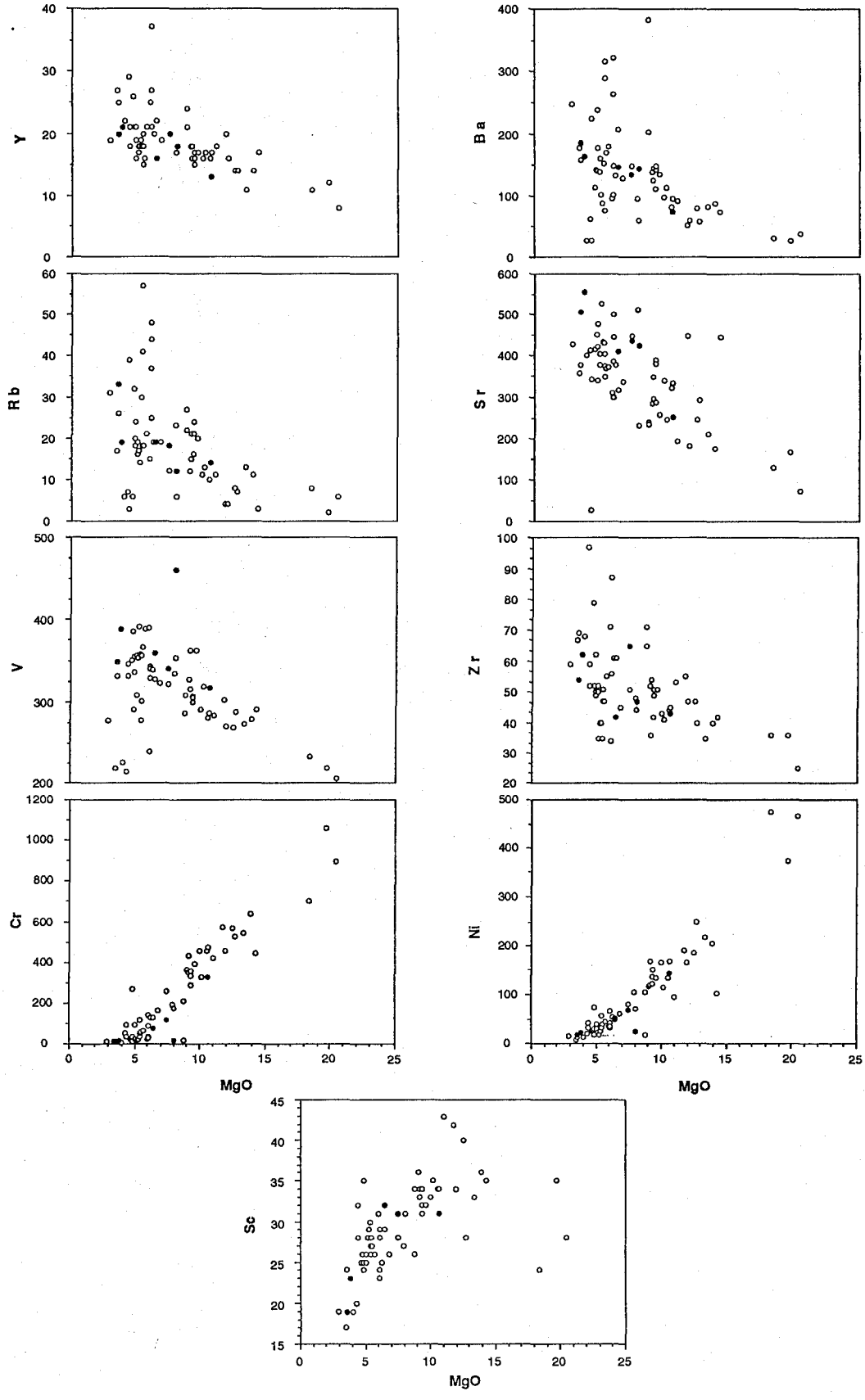

FIGURE 2-18b. Projections of Mantle Volcanics Formation intrusive rocks into planes defined by MgO and analysed trace elements. ○ = dike cores, ● = dike margins. Trace element units are ppm.

Major and trace element variation diagrams based on an MgO abscissa are shown in figure 2-18 a, and b. The major elements display varying degrees of correlation, the best being in projections of Al_2O_3, CaO and Na_2O. The negative correlations of Al_2O_3 and Na_2O indicate plagioclase cannot be a fractionating phase. Tight grouping of the data in the Al_2O_3 projection indicate the Al/Mg ratio is nearly constant throughout the whole fractionation process, and therefore best reflects the relative degree of evolution of any member of the suite. The effect of clinopyroxene fractionation is shown in the positive correlation of CaO with MgO with the three points lying off the main data trend in the direction of olivine. The "blunderbuss" pattern displayed in FeO is the result of varying amounts of magnetite fractionation evidenced by the groundmass analyses falling in and around the field defined by the bulk analyses. Fractionation of analysed clinopyroxene and realistic olivine phase compositions would have little effect on bulk FeO of these rocks. This is displayed to a lesser degree by the scatter in TiO_2 as it is a significant component in magnetite (see Appendix 2). The slope increase in SiO_2 below about 5% MgO marks the onset of fractionation of a silica depleted phase, magnetite, and is accompanied by an increased degree of scatter.

There is a distinct break in the population at about 15% MgO with three samples (58929, 58932, 58942)[1] anchoring the most magnesian end of the suite. Analysed groundmass compositions (data and technique described in Appendix 1) in all cases fall within the general population spread and along the evolution trend suggesting whole rock compositions represent points not far removed from liquid lines of descent.

The highly compatible trace elements nickel and chromium, which are partitioned into olivine and clinopyroxene respectively, display positive correlation with MgO as a result of fractionation of liquidus phases magnesiochromite (minor), chrome diopside and olivine. These two elements also show a good correlation with each other (fig. 2-19) arguing for their fractionation or accumulation in nearly constant proportion. Two of the three most primitive samples lie off the main trend of the data and are enriched in nickel relative to chrome. These samples may have accumulated olivine with respect to the main trend or, if they are parental, would begin crystallising within the primary olivine phase volume. Fractionation of olivine alone from melts of these compositions is required to attain the trend.

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[1] Sample 58929 is olivine and clinopyroxene megacrystic with megacrysts to 2 cm and smaller 0.9 mm phenocrysts of olivine, clinopyroxene and plagioclase. Both populations are idiomorphic to subidiomorphic and together make up to nearly 50% (by volume) of the rock. These are set in an intergranular olivine, clinopyroxene and plagioclase matrix with average crystal size 0.18 mm.

Sample 58932 is similar to 58928 but with fewer and smaller (3 mm) megacrysts and rare plagioclase phenocrysts.

Sample 58942 is olivine, clinopyroxene and rare plagioclase phyric with idiomorphic to subidiomorphic phenocrysts 0.4 to 1.8 mm set in an intergranular matrix of 0.1 mm olivine, clinopyroxene and plagioclase.

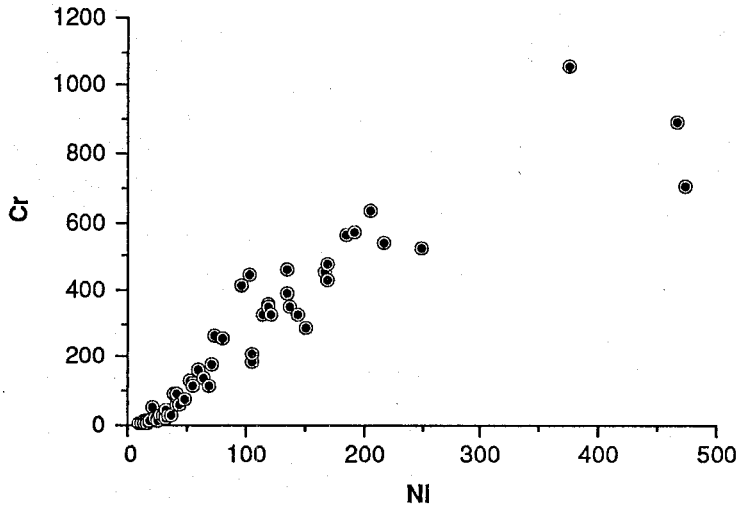

FIGURE 2-19. Projection of Mantle Volcanics Formation intrusive rocks into the Ni:Cr plane. The good correlation of these two compatible trace elements, which are strongly partitioned into olivine and clinopyroxene respectively, indicates both phases are either being fractionated or accumulated in nearly constant proportion.

The negative correlation of strontium, which would be a compatible element during plagioclase crystallisation and fractionation, suggests this process was not occurring. Scandium, which is compatible with clinopyroxene, shows much the same pattern as CaO, that is an initial enrichment from the most magnesian samples then a steady depletion below about 13% MgO. The elements Y, Rb, Ba, V and Zr have positive correlations commensurate with their incompatibility in the fractionating magma system.

Fractionation history

The genesis of the MVF intrusive rocks is difficult to establish rigorously. The phenocrystic nature of the rocks strongly suggests their bulk chemistry may have been altered by having accumulated phenocryst components in excess of those in solution in the most primitive parental liquid. The multiple phyric phases and mineralogical reconstitution of olivine and plagioclase presents a severe limitation to mathematical "reversing" methods such as that used by Nye and Reid (1986) or least-squares component-space transformations to arrive at an estimated primitive liquid. Without accurate phase compositions, mass balance and equilibrium calculations to determine the degree of accumulation must be performed with estimates. Although it is possible to estimate reasonable compositions for the altered phyric phases, these estimates are not precise enough for rigorous calculations.

One method of testing the viability of possible parental liquids is to assume a bulk rock composition represents a parental liquid and then "crystallise" it numerically, checking the results against phase and related bulk rock analyses from the suite and experimental data from rocks of similar composition. Using the computer program EQUIL (Nielsen 1985 and Appendices 3 and 4) a locus of points can be generated which simulates the liquid line of descent at one atmosphere for any given initial liquid composition. Using

simulation conditions of equilibrium crystallisation, oxygen fugacity of the QFM buffer, no spinel or orthopyroxene crystallisation, a liquid line of descent has been generated from sample 58929 which is shown on the diagrams in figure 2-20. The lines follow the general trend of the data quite well until the inflection marking the onset of plagioclase crystallisation at which point scatter of the data becomes more pronounced. This suggests two possibilities:

1- plagioclase crystallisation was suppressed to varying degrees, possibly due to the effects of P_{H_2O} (Perfit et al. 1980; Gill 1981), allowing the liquid to become enriched in constituent components. When plagioclase did begin to crystallise the liquid moved away from the olivine-clinopyroxene cotectic on a line sub-parallel to the predicted olivine-clinopyroxene-plagioclase cotectic or;

2- separation of plagioclase from the liquid was less effective than either olivine or clinopyroxene leading to a liquid containing phenocrysts such that the bulk rock chemistry was little changed.

The calculated liquid lines of descent for the other two most mafic samples (58932 and 58942) are parallel to that shown in figure 2-20 but displaced slightly due to their different initial starting compositions. The inflections indicate that clinopyroxene becomes a liquidus phase between 9.5% and 10.5% and plagioclase between about 8% and 9% MgO. This being the case, analysed groundmass compositions, even of the most mafic samples, should not be greater than about 9% MgO as all samples have plagioclase as a liquidus phase. In figure 2-20 it can be seen that this is the case.

Liquidus temperatures calculated for sample 58929 using EQUIL and other methods and determined by experiment on a similar sample from New Georgia by Brown and Schairer (1968) are shown in figure 2-21. EQUIL calculated temperatures are always higher than the those from New Georgia, but have the same crystallisation sequence, i.e. olivine→clinopyroxene→plagioclase. The higher EQUIL temperatures are most likely due to using an anhydrous re-calculated initial liquid chemistry which would be slightly higher in MgO and tend to displace temperatures upward. The temperatures calculated using the method of French and Cameron (1981), although close to EQUIL temperatures for olivine and plagioclase, produce a olivine→plagioclase→clinopyroxene crystallisation sequence. Since this method is derived from a multi-variate analysis of a basaltic data set with a large number of MORB type samples, this relationship is to be expected as MORB generally crystallises clinopyroxene last if at all (Grove and Bryan 1983; Bryan et al. 1981).

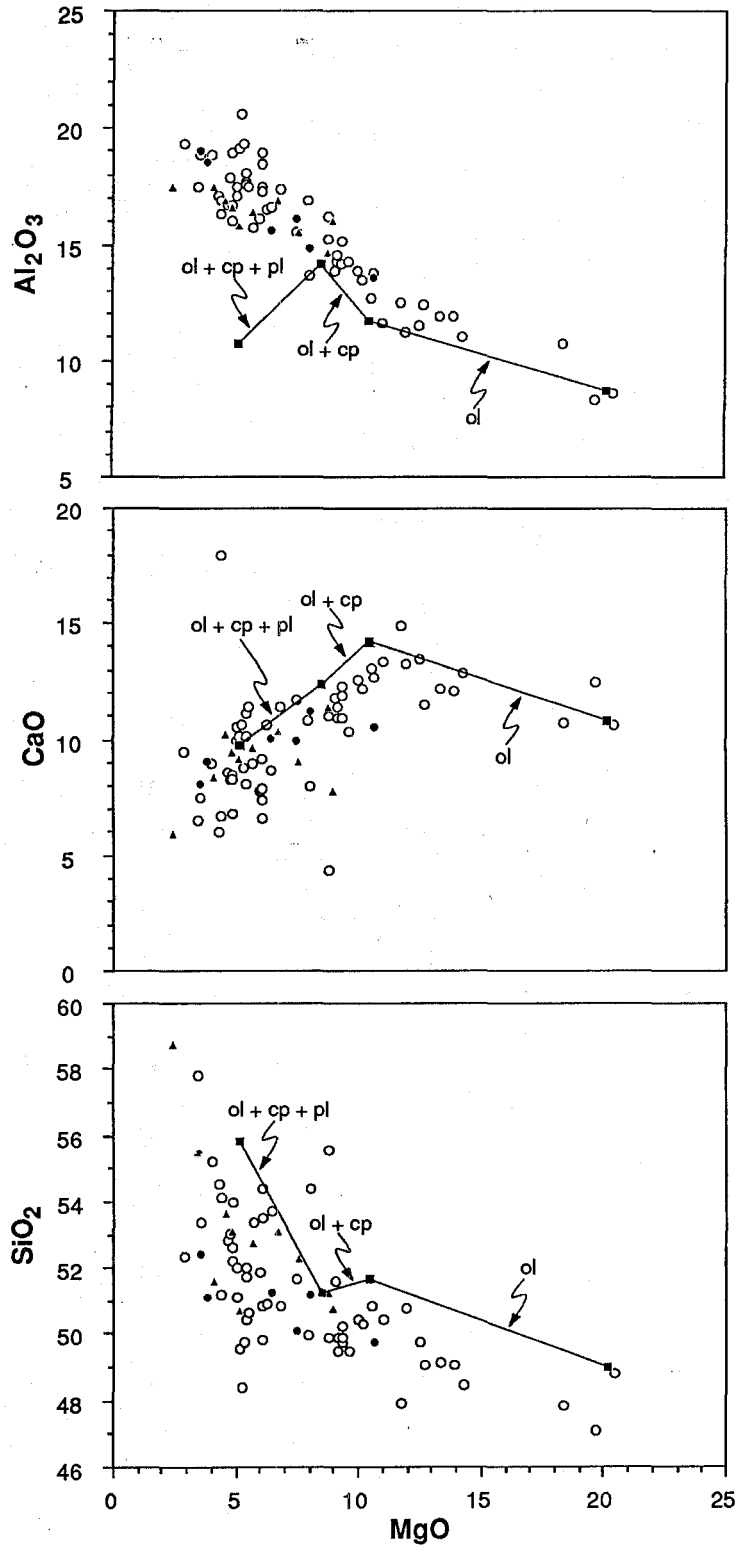

FIGURE 2-20. Three projections from figure 2-18a, with an EQUIL calculated liquid line of descent under the conditions of equilibrium crystallisation, QFM buffer and no spinel or orthopyroxene crystallisation. Symbols are the same as in the previous figure with the addition of ■ which mark end points of crystallisation sequences connected by tie-lines. The calculated liquid paths are not actually linear due to solid solution effects, but approach linearity at this scale so have been shown by tie-lines for clarity. The tie-lines are labeled as to the phases calculated to be crystallising along them. Calculated liquidus temperatures decreasing with MgO content are:1418.31°C (olivine), 1228.32°C (clinopyroxene) and 1180.45 (plagioclase). The last end point is where the program was terminated and has no inherent significance.

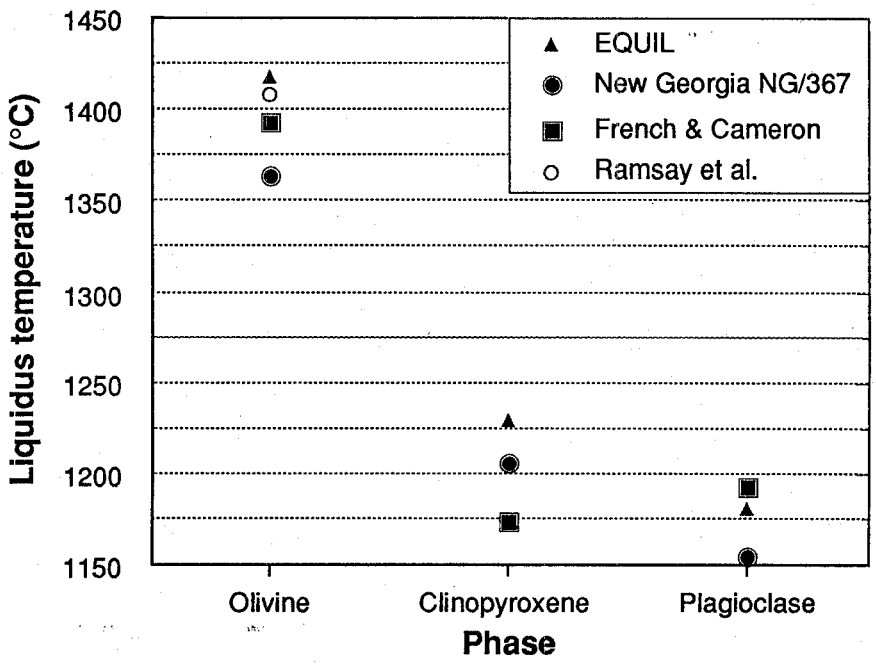

FIGURE 2-21. Comparison of liquidus temperatures calculated for sample 58929 and determined by the melting experiments of Brown and Schairer (1968) on a sample of similar chemistry from New Georgia collected by Stanton and Bell (1969).The calculated temperatures are from the computer program EQUIL and by the method of French and Cameron (1981). The calculated olivine temperature by the method of Ramsay et.al. (1984) is found using the empirical relationship: T(°C) = 16.307 * MgO + 1 083

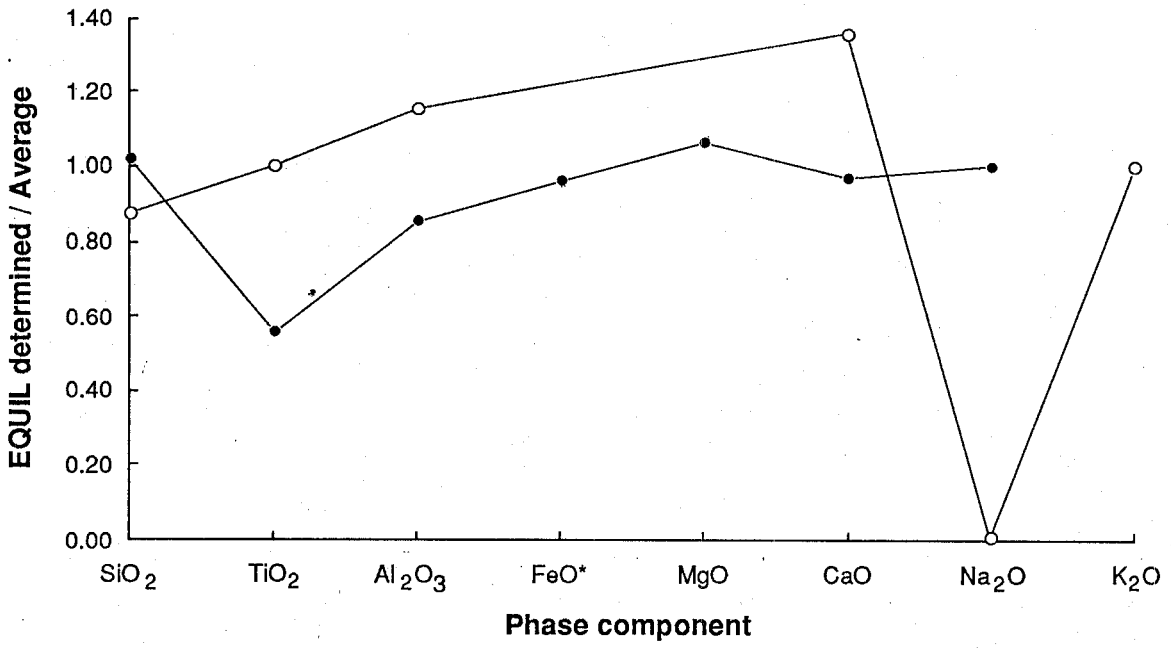

FIGURE 2-22. Comparison of phase compositions determined for sample 58929 using EQUIL and averages of the highest temperature compositions analysed in the suite. The EQUIL values are normalised against the analysed values so that perfect comparison is one. ○ = plagioclase, ● = clinopyroxene.

Phase compositions determined using the EQUIL model are compared with averages of the highest temperature phase compositions analysed in the MVF intrusives in figure 2-22. EQUIL determined values are normalised against analysed values so that a perfect comparison is one. Clinopyroxene compares very well with the only significant deviation in TiO_2. Plagioclase shows a strong deviation in Na_2O and CaO and corresponding antithetic SiO_2, Al_2O_3 deviations. This is due to the exceptionally low starting value for Na_2O used in the model (0.01%) most likely the result of analytical error in the determination of Na_2O (see Appendix 1). The composition of forsterite determined by the EQUIL model for sample 58929 when clinopyroxene becomes a liquidus phase is Fo_{86}. The value determined from an average of five of the most mafic analysed clinopyroxenes using equation 2b[2] of Barsdell (1988) for rocks of similar composition is $Fo_{86.9}$, quite a good agreement.

Both the cores and margins of the larger dikes were sampled separately (Plate 1P in pocket) and show varying degrees of evolution (fig. 2-23). Where the initial input composition to EQUIL is a dike core which has a sampled margin and/or estimated "liquid" (analysed groundmass) compositions, the calculated liquid lines of descent pass close to these more evolved compositions (figure 2-24). This could be accounted for by a simple accumulation process if the dikes contained only a single phyric phase, as oversaturation in the phyric phase would cause the liquid to move directly toward the accumulating phase, but considering that all of the dikes have reached the olivine–clinopyroxene–plagioclase cotectic, the fact that the predicted liquid lines of descent pass through or close to more evolved dike margin and groundmass compositions, implies that the phenocryst content of the more mafic cores has either been acquired by crystallisation without significant fractionation or phenocrysts have accumulated in the same proportions as their crystallisation ratio.

From the above discussion it is clear that the parental magma for the whole suite of MVF intrusive rocks probably had a composition close to the three most magnesian samples. Fractionation of olivine, clinopyroxene and to a lesser extent plagioclase of compositions either determined analytically or estimated could produce the range of compositions sampled. Crystallisation was most likely under low pressure conditions from high temperature melts emplaced to a high level beneath an active island arc, later to be injected as dikes and sills. Many of the dikes were probably feeders to surface vents, the eruptive products of which are represented in the enclosing pyroclastic sediments.

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[2] An empirically derived relationship between associated olivine and clinopyroxene in cumulate nodules and olivine inclusions in clinopyroxene phenocrysts which can be expressed as:

$$100 * \frac{Mg}{(Mg + \Sigma Fe)_{Cpx}} = 0.8793 * Mg^{\#}_{Ol} + 13.36$$

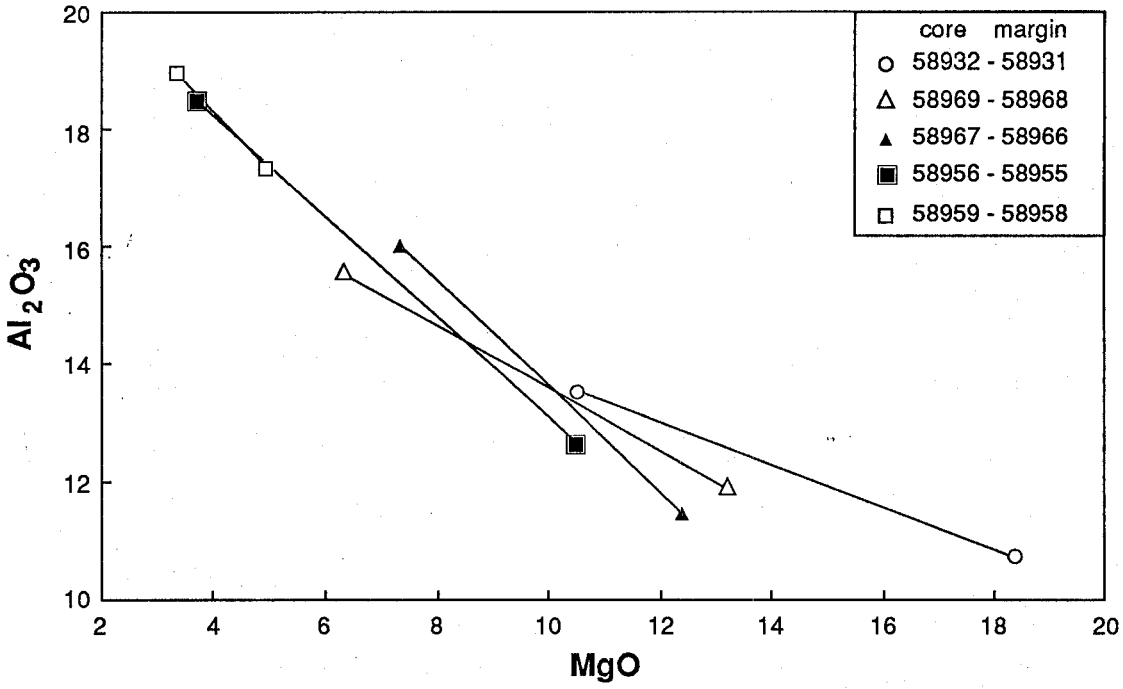

FIGURE 2-23. MgO:Al_2O_3 projection of sampled dike cores and margins. Cores are always more magnesian than the margins.

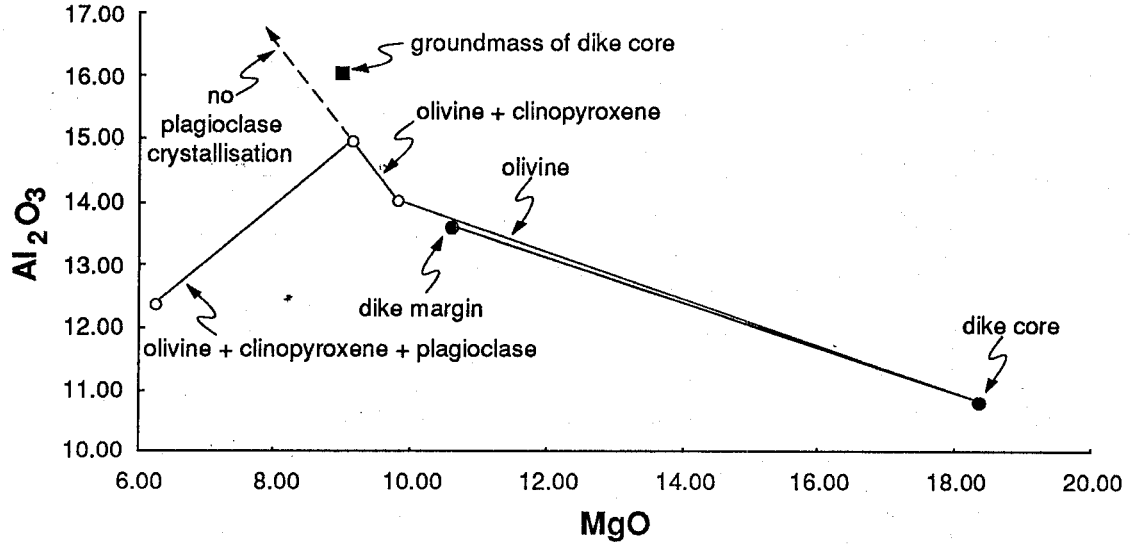

FIGURE 2-24. MgO:Al_2O_3 projection of a dike margin (58931), dike core (58932) and its analysed groundmass, along with EQUIL calculated liquid line of descent with phase liquidii labeled. The olivine-clinopyroxene vector is extended to show the effects of suppressed plagioclase crystallisation. Note that the more evolved dike margin lies very close to the calculated liquid path and the core groundmass composition is not far off the plagioclase suppressed path.

Trace Elements

Analyses were obtained for eighteen trace elements and are shown in Appendix 1. Due to limitations of the XRF technique at low concentrations, accurate values only were obtained for ten of these.

Trace elements can used to investigate further the fractionation model for the suite and petrogenesis of the parental magma. These elements are essentially independent of complex major element exchange reactions which can often blur the relationship between fractionating phases in major element projections. In this suite, compatible trace elements show similar patterns to major element variation in response to fractionation. In the Ni:Sc plane (figure 2-25) the pattern is similar to that of MgO:CaO, that is, an initial enrichment and then steady depletion of the component in clinopyroxene (Sc and CaO) with decreasing component in olivine (Ni and MgO). The good correlation between Sc and Ni below 250 ppm indicates the fractionation ratio of olivine:clinopyroxene is fairly constant. This is shown more clearly in the plane of MgO:Ni/Sc (figure 2-26) where the three high MgO samples drop almost vertically as a result of initial olivine fractionation and below 15% MgO the Ni/Sc ratio decreases linearly with decreasing MgO indicating a nearly constant fractionation ratio.

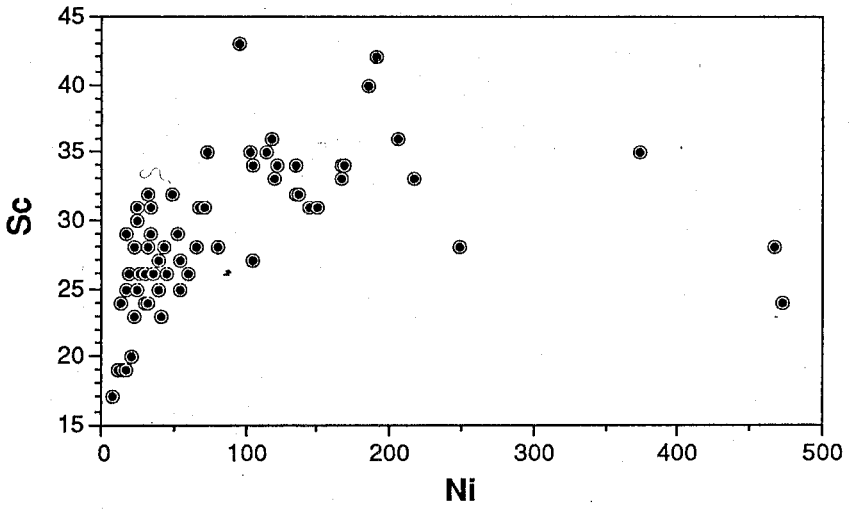

FIGURE 2-25. Ni:Sc projection of whole rock analyses of Mantle Volcanics Formation intrusives in ppm units. The enrichment of Sc then steady depletion with decreasing Ni indicates initial olivine then olivine and clinopyroxene control of fractionation. The reasonably good correlation of Sc with Ni below 250 ppm Ni suggests the olivine:clinopyroxene fractionation ratio is fairly constant.

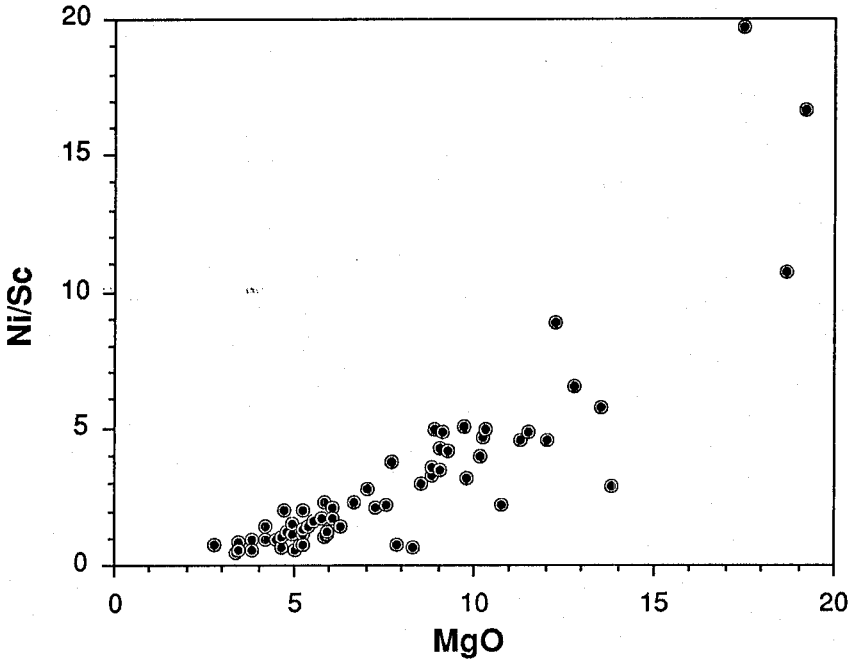

FIGURE 2-26. MgO:Ni/Sc projection of whole rock analyses of Mantle Volcanics Formation intrusives in ppm units. The good correlation below 15% MgO between the ratio of the trace elements Ni and Sc which are preferentially partitioned into olivine and clinopyroxene respectively and decreasing MgO, is evidence of a nearly constant fractionation ratio between these two phases.

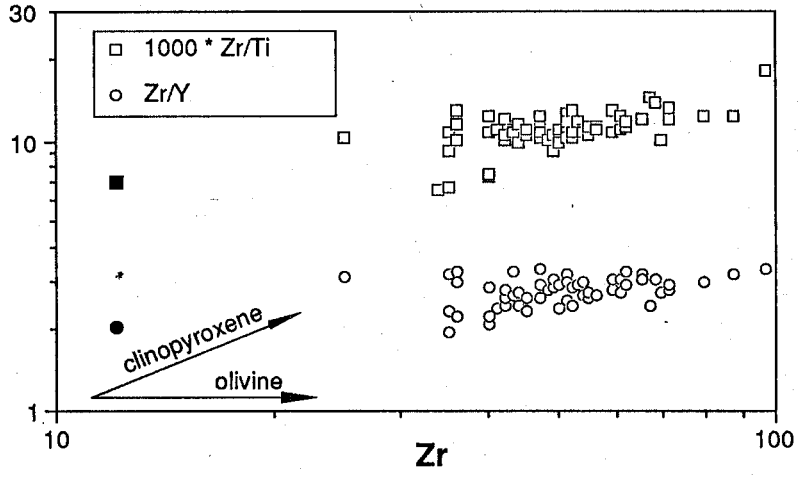

FIGURE 2-27. Zr:Zr/other projection of whole rock analyses of Mantle Volcanics Formation intrusives in ppm units where other is Y and Ti/1000. The closed system fractionation vectors shown are from Pearce and Norry (1979) for Y and represent 50% crystallisation of the phase. The difference in mineral-melt distribution coefficients for Y and Ti for the phases is small enough such that the vectors can easily be applied to the Zr/Ti projection at this scale. Filled symbols are values for estimated primordial mantle (Wood et al. 1979)

Pearce and Norry (1979) modelled the effects of a number of petrogenetic processes on the concentrations of Zr, Y and Ti showing that closed system fractionation in basic magmas of olivine, clinopyroxene and plagioclase, tends to have little effect on Zr:Y and Zr:Ti ratios. Nearly flat linear trends are produced when a suite of rocks related by this process are projected into planes of these ratios and Zr, with Zr representing an index of fractionation. Figure 2-27 shows the MVF intrusives projected into the planes Zr:Zr/X where X is Ti/1000 and Y. The linear trend of the data clearly indicates a closed system fractionation process was operating to produce the variation observed in the MVF intrusives. In these types of projections the effect of partial melting of realistic mantle mineralogies produces gentle concave upward curves which approach linearity only at high degrees (>30%) of melting (Pearce and Norry 1979). Extrapolation of the linear trends of both data sets can be seen to intersect the values for estimated primordial mantle (Wood et al. 1979). This argues that for the parental magma of the MVF intrusives suite to have been generated from mantle of this composition, a large degree partial melting event possibly with some degree of fractionation of olivine enroute to the surface is required.

In magnesian primary magmas derived from high degrees of partial melting of mantle peridotite, major element ratios Ca/Ti, Al/Ti, Ca/Al and incompatible element ratios should approximate source mantle values (Ramsay et al. 1984). These ratios for the three most magnesian rocks of the MVF intrusives and other suggested primary magmas are shown in figure 2-28. The values have been normalised to chondrite (Nesbitt and Sun 1980) and show only small deviation from this inferred source type. Patterns and values for the MVF rocks and suggested parental magmas of the picrite-ankaramite arc suites for New Georgia, Aoba, Merelava and Okmok are similar for most ratios. The greatest deviation from the general pattern is in the Merelava values particularly in Zr/Sc which may be the result of a degree of clinopyroxene accumulation.

Values for selected hygromagmatophile elements normalised to the estimated primordial mantle of Wood et al. (1979) for the three most primitive MVF compositions and four suggested primary magmas of modern island-arc suites are shown in figure 2-29. The overabundance of alkali and alkaline-earth LIL (Rb, Ba, K, Sr) and relative depletion of HFS (Zr, Ti, Y) elements with respect to MORB is a distinguishing feature of island-arc magmas (Perfit et al. 1980) and has been suggested to be a result of mantle metasomatism from variably enriched components derived from the subducting slab (Jakš and Gill 1970; Wood et al. 1979; Geist et al. 1986). The MVF samples are seen to be clearly arc derived and compare favourably with primary magmas of other arc suites suggesting they may also be primary with melt generation having taken place under similar petrogenetic conditions.

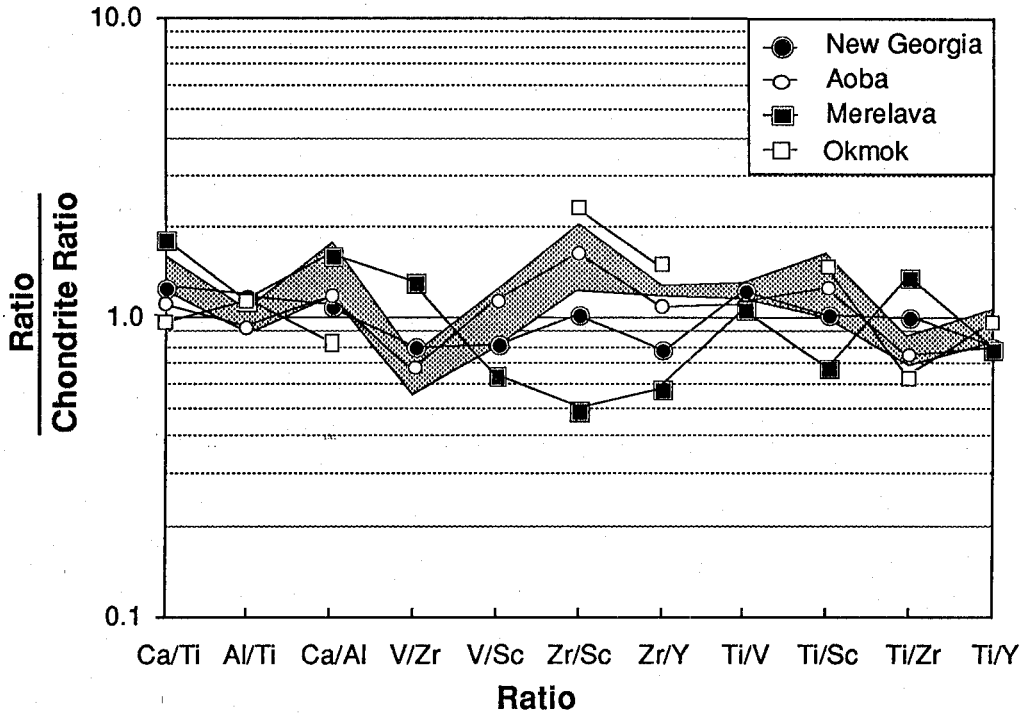

FIGURE 2-28. Major and incompatible element ratios of the MVF intrusives and other suggested primary arc magmas. The range of values for the three most primitive MVF intrusive samples 58929, 58932 and 58942 is shaded. Data sources are: New Georgia, Ramsay et al. (1984); Aoba, Gorton (1977); Merelava, Barsdell (1988); Okmok, Nye and Reid (1986)

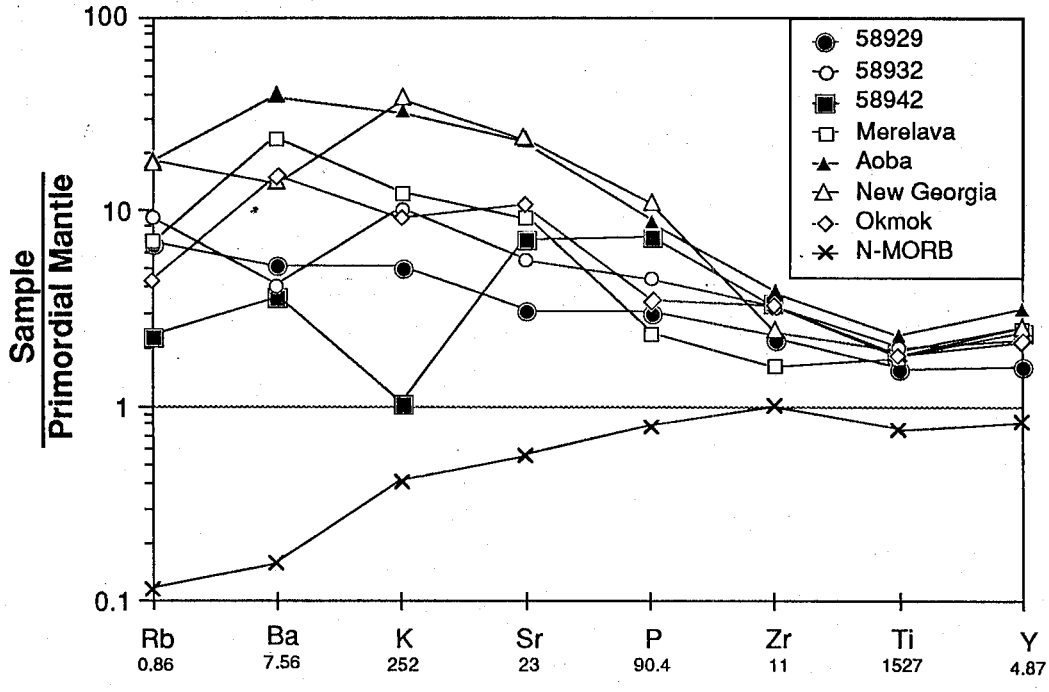

FIGURE 2-29. Selected *hyg* element abundances of the most primitive MVF intrusives, other suggested primary arc magmas and average *N*-type MORB. Values are normalised to estimated primordial mantle abundances of Wood et al. (1979) (shown beneath the respective element) and arranged in increasing order of bulk partition coefficients between upper mantle mineral assemblages and basaltic melts. Data sources are: New Georgia, Ramsay et al. (1984); Aoba, Gorton (1977); Merelava, Barsdell (1988); Okmok, Nye and Reid (1986)

Conclusions based on geochemistry

The intrusive rocks of the MVF display the general characteristics of primitive island-arc magmas, namely highly calcic plagioclase, chrome rich spinels and K-group enrichment relative to HFS elements. The three most primitive samples (58929, 58932, 58942) have high Mg#'s (fig. 2-30), chrome and nickel abundances and nearly chondritic incompatible element ratios, characteristics similar to proposed primary magmas from other island-arcs (Basaltic Volcanism Study Project 1981). Although these three MVF intrusive samples are phenocrystic, their trace element chemistry and calculated evolution paths suggest their phenocryst contents are probably not a product of extensive crystal accumulation and probably represent something close to the ultimate parental composition for the suite. This ultimate parental composition looks to be a primary mantle derived melt generated by large degree melting episodes of source composition similar to that beneath most island-arcs which has been little modified on ascent and emplacement into high crustal levels. Unfortunately, rare-earth element and isotopic data are required to define more clearly the early stages of the petrogenetic history of the MVF; these data were not obtained in the course of this study.

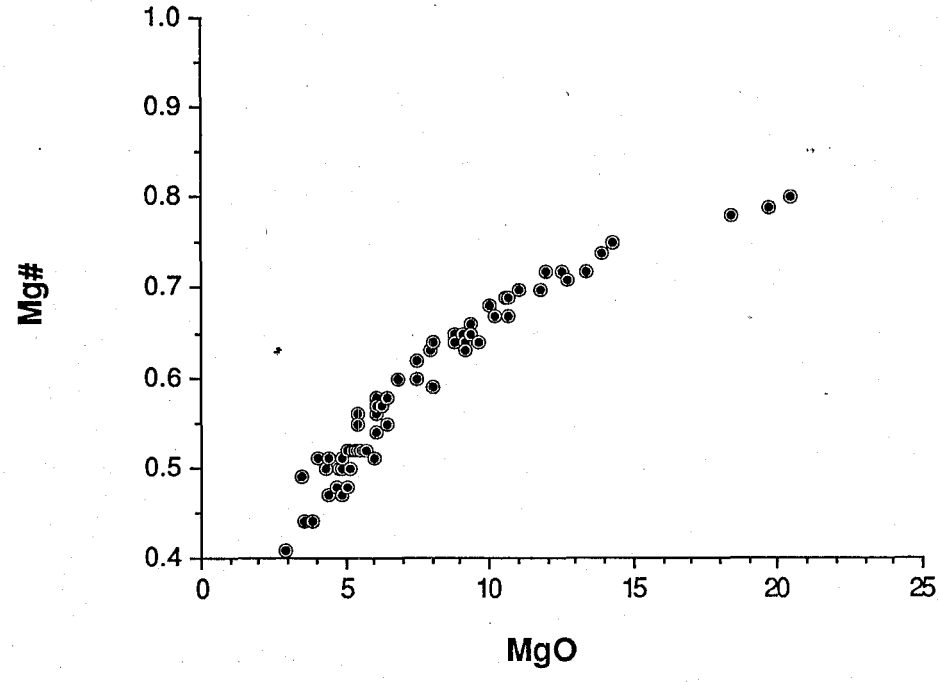

FIGURE 2-30. Mg number* plotted against MgO for all analysed samples of the Mantle Volcanics suite. Samples between Mg# 0.70 and 0.83 could have potentially been in equilibrium with mantle olivine ranging in composition between $Fo_{90\text{-}94}$ assuming $K_{Ol/liq}^{Fe/Mg}$ varies between 0.27 and 0.33 (Basaltic Volcanism Study Project 1981).

* $Mg^{\#} = \text{molar}\frac{Mg}{Mg + Fe^{2+}}$ where $\frac{Fe^{2+}}{\Sigma Fe} = 0.85$

Geochemical comparison with other Pre-Cretaceous arc-volcanics in the South Island

Published whole rock major element analyses of samples from the Plato and Largs terranes, the Takitimu Group, the Brook Street Volcanics of D'Urville Island and the MVF intrusives are projected into the $CaO:Al_2O_3:MgO$ plane are shown in figure-2-31.

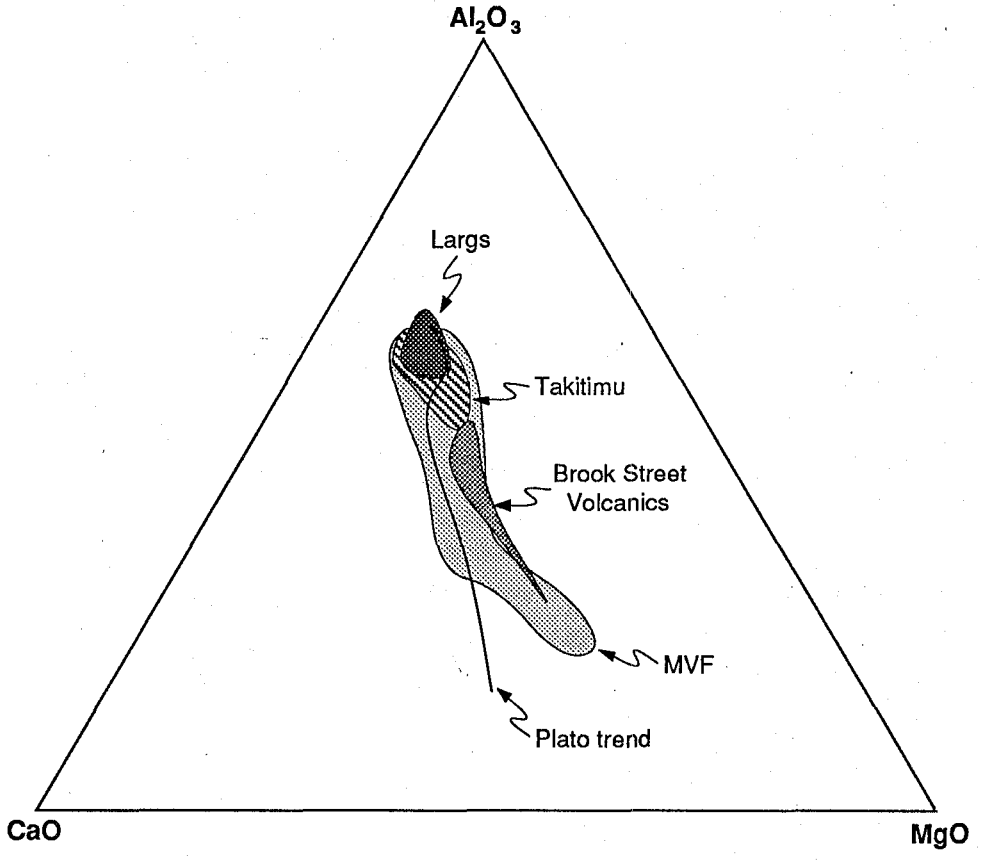

FIGURE 2-31. Projection of analyses of pre-Cretaceous arc volcanics of the South Island into the plane $CaO:Al_2O_3:MgO$ (weight %). Data sources: Plato and Largs-Williams and Smith (1979); Takitimu-Houghton (1985), analyses 2-13; Brook Street Volcanics (D'Urville Island)-Sivell and Rankin (1983); MVF-Appendix 1.

The Takitimu Group and Largs terrane overlap the MVF field and Plato terrane trend only at the most evolved compositions. The Plato terrane and MVF samples span a similar range and have co-directional evolution paths with the deviation of the Plato terrane at lower Al_2O_3 values probably due to enrichment in clinopyroxene component over that in solution of the parental magma. The Brook Street Volcanics show a similar trend to the MVF but within a more restricted compositional range. Williams and Smith (1979) showed the Plato and Largs terranes to be distinctly different partly on the difference in chondrite normalised REE patterns. The Plato displays a flat trend with no enrichment of the light relative to heavy rare earths whereas the Largs terrane shows a significant enrichment of the LREE's. The Takitimu Group REE pattern (Houghton 1985) is similar to that of the Largs terrane indicating the petrogenetic histories of these suites are probably more similar to each other than to the Plato terrane. Like the Plato, Brook Street Volcanics basalts also have flat REE trends (Sivell and Rankin 1983) and are similar to both the Plato and

the MVF in major element chemistry and the occurrence of ankaramites and ankaramitic basalts. No REE data has been collected to date for the MVF but considering the other characteristics in common with the Plato terrane and Brook Street Volcanics, the REE patterns would no doubt be similar.

SUMMARY

The Mantle Volcanics Formation is a small but unique and important segment of the belt of Permian island arc related rocks running through the South Island. It is composed of near vent marine facies of predominantly very coarse tuffaceous breccias and crystal rich tuffaceous sandstones of pyroclastic and epiclastic origin deposited in the main by debris flows and high density turbidites. This sedimentary pile has been intruded, up to 40% by volume and often while still wet, by a continuous spectrum of tholeiitic magmas ranging from exceptionally mafic ankaramites to high-K, high alumina basaltic andesites in the form of dikes, sills and small stocks. The intrusives were most likely part of a feeder system to a vent which was at least at some time sub-aerial. This part of the arc was under a strongly anisotropic tensional stress regime which was probably deep seated allowing mantle derived primitive magmas access to the surface. Crystallisation enroute to the surface in high aspect ratio magma chambers while under a net upward flux (Maaløe 1987) produced highly phenocrystic magmas in some cases little evolved from the ultimate parental melt. Subduction of linear oceanic topographic features such as ridge crests and fracture zones or young oceanic crust produces tectonic discontinuities in the overriding plate (Taylor et al. 1980; England and Wortel 1980; Fisher 1986). Primary picritic and ankaramitic volcanism has been suggested as being related to tectonic complexities such as these (Dunkley 1983; Ramsay et al. 1984; Foden and Varne 1983) and the MVF may record a similar tectonic situation in the Brook Street Terrane.

TWIN LAKES TRONDHJEMITE AND ASSOCIATED ROCKS

INTRODUCTION

The name Twin Lakes Trondhjemite (TLT) is given to a tabular, composite plutonic body of predominantly trondhjemitic[1] composition containing rafts and xenoliths of Mantle Volcanics Formation (MVF) lithologies interposed between the MVF on the east and the Skippers Formation (SF) on the west (see map in pocket). The type locality is the area between the Wilmot Fault at the "Twin Lakes" (GR 090427) and the Wilmot River. Both the eastern and western contacts are steeply dipping faults often displaying post-glacial vertical displacement. Near the contacts rocks are often cataclastically deformed and sheared with an incipient foliation. The northern and southern extremities of the body have not been investigated and are mapped as inferred on the basis of geomorphology and the absence of TLT in outcrop along the shore of Lake McKerrow. Greenschist facies mineral assemblages occur throughout. A single chemical analysis (58928) is presented in Appendix 1.

At the type locality, pyroxene and amphibole phyric basic pods and rafts, some of mappable size, occur within the TLT and are interpreted as xenoliths and stope blocks of MVF. The eastern contact with the MVF is in general sheared and deformed but locally epipheses of TLT occur within the MVF. Near the western contact granitoid dikes and associated sulphide alteration zones are found within the SF. This contact was probably originally intrusive and has been subsequently faulted and deformed.

Nauman (1971, 1973) mapped a group of rocks in the southern Skippers Range between the Wilmot Fault on the west and the "Camp Fault" on the east, containing the Hidden Flats Formation, Camp Conglomerate and granitoid rocks of the MacKay Intrusives[2]. He described the Hidden Flats Formation as consisting of two rock types, a greenstone with a relict pyroxene phyric volcanic texture and hornfelsed tuffaceous sediment also containing relict clinopyroxene. The area where these rocks crop out (GR 048348) is poorly exposed and contacts are equivocal. Observations in the northern

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1 Classifications based on the scheme of Streckeisen (1976).

2 The MacKay Intrusives were originally defined by Grindley (1958) as "...medium to coarse-grained igneous rocks which intrude the Eglinton Volcanics in the Eglinton Valley." Landis and Waterhouse (1966) raised the Eglinton Volcanics to Sub-group status and placed them, along with the Skippers Formation into the Alabaster Group (see figure 2-32). Nauman (1973) redefined the MacKay Intrusives "...to include all those medium-grained to coarse-grained crystalline rocks which intrude the Eglinton Sub-group." Williams (1975) and Williams and Harper (1978) provisionally accepted this definition for the nomenclature of plutonic rock suites in the Eglinton Valley.

part of the Range suggest that Nauman's Hidden Flats Formation probably represents xenoliths and hornfelsed sediments of Mantle Volcanics Formation within and surrounding the TLT. As such it was rejected as a valid or useful mapping unit.

The Camp Conglomerate (59021) is a very small and quite enigmatic unit which was not investigated in detail during the course of this study. It is for the most part tectonised and highly fractured both across and between clasts. Contact relations are obscure and absolute boundaries could not be located though it is probably fault bounded. Clasts range in size from 20 to less than 2 cm, are well rounded to sub-angular and supported in a matrix of medium to coarse quartzo-feldspathic sand. Clast types include pink and white granitoids, sedimentary quartzites, and a range of fine grained volcanic clasts including pseudomorphed olivine and plagioclase phyric types with felted or pilotaxitic groundmass texture. None of the volcanic clasts observed have the distinctive clinopyroxene phenocrysts of the MVF. The matrix is composed almost entirely of the greenschist facies mineral assemblage quartz, alkali feldspar and albite with small amounts of actinolitic amphibole and chlorite. Grain contacts of the matrix show evidence of recrystallisation. Conglomerate units of similar clast composition and proximity to Brook Street Terrane rocks are reported at Productus Creek, Southland (Barrets Conglomerate of Jurassic age, Aslund 1988; Landis 1987) and Pepin Island, Nelson (Fall Conglomerate of unknown age, Lauder 1964) and the Camp Conglomerate may be correlative to one or both of these.

Petrography of granitoid rocks

The TLT is predominantly a medium to coarse grained (<1 to 2 mm) trondhjemite with a hypidiomorphic-granular texture (58928). It is for the most part composed of albitised plagioclase (70% to 80%), quartz (20% to 30%), minor alkali feldspar and less than 10% mafics.

Locally in small areas, substantial amounts of alkali feldspar occurs in place of plagioclase and these rocks are true granites (59022). The boundaries of these bodies are not exposed but they are probably more evolved portions of the trondhjemite pluton. Plagioclase is generally euhedral to subhedral with albite twinning often bent and kinked. The grains appear dusty in plain light due to fine, disseminated inclusions of epidote and sericite. Quartz is anhedral and interstitial to the feldspars and shows strained extinction. In the granitic segregations, alkali feldspar is often pink and appears "rusty" in thin section probably due to fine haematitic inclusions. These feldspar grains are often fractured along cleavage planes and these are filled with white mica (?muscovite). Mafics are actinolitic amphibole possibly after original pyroxene and chlorite probably after biotite. Euhedral titanite to almost 1 mm is not uncommon. Fractures and zones of cataclasis were observed both in thin section and outcrop scales.

Pods and dike like bodies of ?metabasite (59023) occur within the TLT. These are composed of actinolitic amphibole (60% to 80%), highly altered plagioclase and trace amounts of titanite. The relationship of these rocks to the TLT in which they occur is unclear.

Summary

The TLT provides an important constraint in the tectonic evolution of the Brook Street Terrane in that it links the Mantle Volcanics and Skippers Formations between which the original relationship is unknown (see Section 4, Skippers Formation and Section 6, Summary and Synthesis). Although the present contacts are faulted, the remnants of original intrusive relations between the TLT and these units indicate that the MVF and SF were spatially associated before emplacement of the TLT, and that it was probably intruded along a fault separating them. A more complete discussion of correlation and implications of the TLT is contained in Section 6, Summary and Synthesis.

SKIPPERS FORMATION

INTRODUCTION

The SF is a fault bounded, tectonised body of ultramafic, volcaniclastic and hypabyssal rocks of greenschist facies metamorphic grade. The Formation crops out extensively only in the Skippers Range and has a structural thickness of approximately 2 km. A fault bounded slice of the Formation may occur in the upper portions of the outliers southwest of the Hollyford-Pyke confluence. From my reconnaissance work on D'Urville Island, it is suggested that the Brook Street Volcanics occurring there are tectonically intermixed with a Skippers Formation correlative.

The Skippers Formation (SF) was first separated from the Eglinton Volcanics of Grindley (1958) by Wood (1962) and placed, with the Eglinton Volcanics, in the Alabaster Group by Landis and Waterhouse (1966). Nauman (1971, 1973), working in the southern Skippers Range, subsequently proposed a formal up-grading of the Formation to a Sub-Group which included three formations; the Lone Stag Layered Complex, Hokuri Dykes and Slabby Peak Schist, delineating distinct lithologic units. As these three units are shown by the present work to be of limited extent and cannot be traced with confidence into the northern Skippers Range, this thesis will follow the scheme of Landis and Waterhouse (1966) with the addition of members to the Formation to resolve lithologic and textural diversity (see fig. 2-32).

CONTENT

The Skippers Formation in the southern Skippers Range is divided lithologically into three members (terminology modified after Nauman (1971, 1973)): Slabby Peak Schist (SPS); Hokuri Intrusives (HI); and Lone Stag Meta-Ultramafic Complex (LSUC). In the northern Skippers Range (north of Hokuri Creek), tectonism has been so severe as to allow only local correlation with the less deformed members in the south. As such, a series of seven members (m_O to m_6) have been defined based on mineralogical and textural differences. Where these cannot be assigned with certainty the Formation is mapped undifferentiated.

Northern Members (described from west to east)

The metamorphic mineral assemblage of all northern members is albite + quartz + chlorite + epidote + actinolite ± muscovite ± fuchsite ± titanite ± calcite. Relict phases are all but absent with the occurrence of chromite relics (surrounded by fuchsite) extremely rare.

Actinolite blastoporphs[1] almost certainly have been derived from original clinopyroxene in the protolith. Evidence of original sedimentary layering is rare.

The complex internal structure of the Formation was not studied in detail but numerous measurements of the foliation and, where possible, fold axes were taken (fig. 4-1). The strike of the foliation generally averages 030° and is steeply dipping though there is significant local variation.

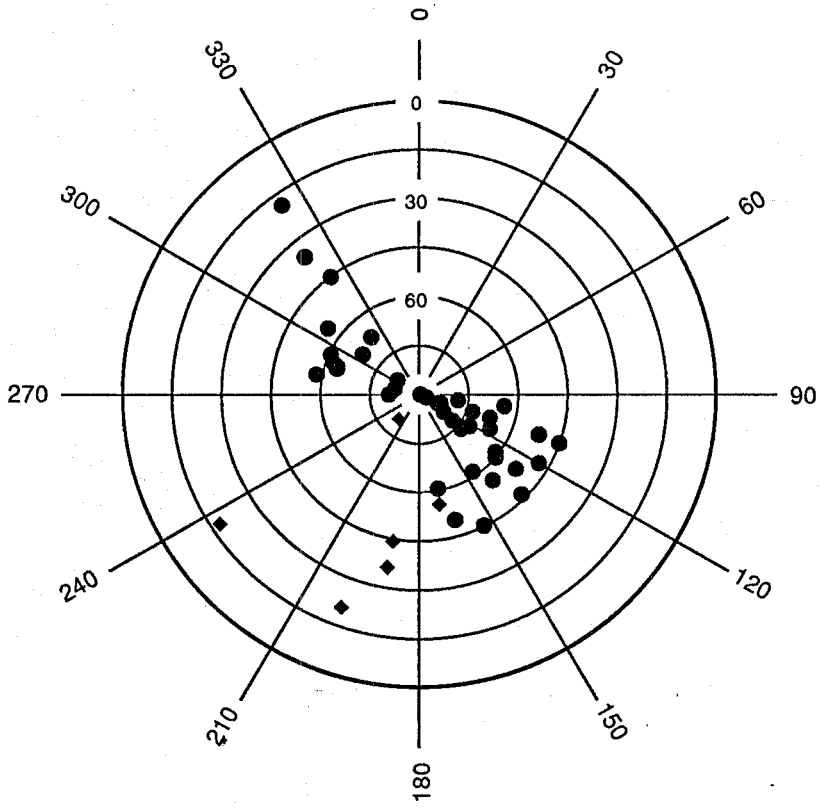

FIGURE 4-1. Measurements of foliation attitudes (●) and fold axes (◆) in the Skippers Formation, northern Skippers Range. Foliation attitudes given as dip (radius) and dip direction (azimuth), fold axes as trend and plunge.

Western Formational Contact - Skippers Fault. Faulted against Slip Hill Granodiorite. Highly sheared and mylonitised, mylonite gradational with Skippers Formation schist to the east. Contact is marked topographically by a "gut" due to differential erosion and possible recent faulting along this line of weakness. Shear zone up to 300 m in width.

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[1] The term *blastoporphs* is used here to refer to the large crystals set in a fine grained groundmass in a rock of relict porphyritic texture termed *blastoporphyritic* (Williams et al. 1954; Spry 1969). In neither of these references was there found a term which referred to completely altered relic phenocrysts.

m_O - A transitional unit between sheared and foliated granitoid (Slip Hill Granodiorite) to the west and rocks of more typically greenschist character (m_1) to the east.

The member is a medium to fine grained schist characterised by a distinctive muscovite sheen on cleaved surfaces. Foliation is good to excellent, steeply dipping east or west of the general NNW strike and defined by quartz banding and muscovite and chlorite lepidoblasts. Cubes of pyrite from 0.1 to 2 mm are common but sporadic in the finer grained layers. Sheared-out microscopic folds are common in thin secetion but mesoscopic folds were not observed in the field.

Contact - Gradational, minor surface expression.

m_1 - Predominantly actinolite blastoporphyritic semi-schist with fine grained, poorly banded, non-blastoporphyritic layers (5-50 cm) and lenses which may be boudinaged. The texture of coarse actinolite blastoporphs with subidiomorphic outlines set in a fine grained matrix (fig. 4-2) suggests derivation from a clinopyroxene phenocrystic protolith such as a dike or sill, flow or crystal tuff. Conspicuous bright green fuchsite mica flakes occur on fresh surfaces.

Varying degrees of shear deformation are apparent from undeformed metamorphic protolithic fabric to incipient foliation and stretching of blastoporphs to severely deformed with a well developed foliation, lineation of blastoporphs and a muscovite/chlorite sheen on the developing rock cleavage (fig. 4-3).

Folding of coarse amphibole banding and the finer lepidoblastic lamination is recognised in outcrops where a view normal to the foliation and lineation may be observed. This occurs on various scales (fig. 4-4 and 4-5) with axes plunging gently south and lying in the plane of foliation.

Extensive foliation bound sulphide alteration zones occur in a few localities (see map in pocket) evidenced by limonite/hematite staining. In thin section these zones show alteration about pyrite and crystallisation of muscovite and chlorite at high angles to the foliation..

m_1 is well developed south of "Jelly Bean Lake" (informal name used during Kennecott exploration (Report MPW No. 10973 (Cromwell) 1970) but becomes more obscure and undifferentiable to the north.

Contact - Fault with associated talc and chlorite schist zone.

m_2 - Very fine grained with good slabby cleavage. The foliation is most noticeable on weathered surfaces due to resistant quartz-feldspar bands. Highly veined and fractured with a characteristic "woody" appearance due to the fine laminae (fig. 4-6) and a slightly rusty colour on weathered surfaces. Small kink folds, tight asymmetric folds, offset quartz veins and quartz filled tension gashes are characteristic (fig. 4-7). Some pyrite cubes were observed otherwise the unit is distinctly non-blastoporphyritic. This member is most similar to the Slabby Peak Schist

member in the southern Skippers Range and was probably derived from a fine grained basic tuff or tuffaceous sandstone protolith.

Contact - Fault with zone of intensive shearing and deformation.

m_3 - Very fine grained (average grain size ≤0.1 mm), faintly banded green rock with small scale tight symmetric and ptygmatic folding (fig. 4-8). Poorly developed axial plane foliation and cleavage. This member was probably derived from a fine grained basic tuff or tuffaceous siltstone.

Contact - Fault.

m_4 - Non-porphyroblastic and fine grained (though coarser than m_3). Deformation is present though not readily apparent due to lack of lithologic layering. Near the contact with unit m_5 a distinctive "grey schist" horizon approximately 10 m thick anastomoses with more typical greenschist. The grey schist (59020) appears to consist of interlayered grey pelitic and coarser green psammitic sediment. Good foliation and poor cleavage.

Contact - Fault.

m_5 - Actinolite granoblastic "knobby" rock, generally massive with poor foliation and schistosity. Local fine grained, more schistose intervals containing lenses and pods of porphyroblastic rock. Deformation zones of severely sheared rock up to 0.5 m wide.

Sample 59001 (fig. 4-9) shows an interesting texture of spheroids from 0.5 to 2 mm of epidote and/or albite which are sometimes displaced along small fractures but otherwise undeformed. These probably are after an original variolitic or amygdaloidal texture. The sample came from a small pod less than 2 m in size and nothing similar to it was observed anywhere else in the Formation.

Contact - Gradational.

m_6 - Very fine grained highly deformed ultramylonite. Folding displayed by thin resistant quartz bands. Away from the eastern contact a large talus block was observed with granitoid apophyses.

Eastern Formational Contact - Wilmot Fault (fig. 4-10) with chlorite and talc schist along trace. Unit to east is the Twin Lakes Trondhjemite.

Southern Members

In the southern Skippers Range protolithic fabrics are for the most part preserved and relict clinopyroxene in the meta-ultramafic rocks is not uncommon. The members here were initially defined and described by Nauman (1971, 1973) and found in the present study to be valid. The member names have been altered slightly to more accurately portray their contents.

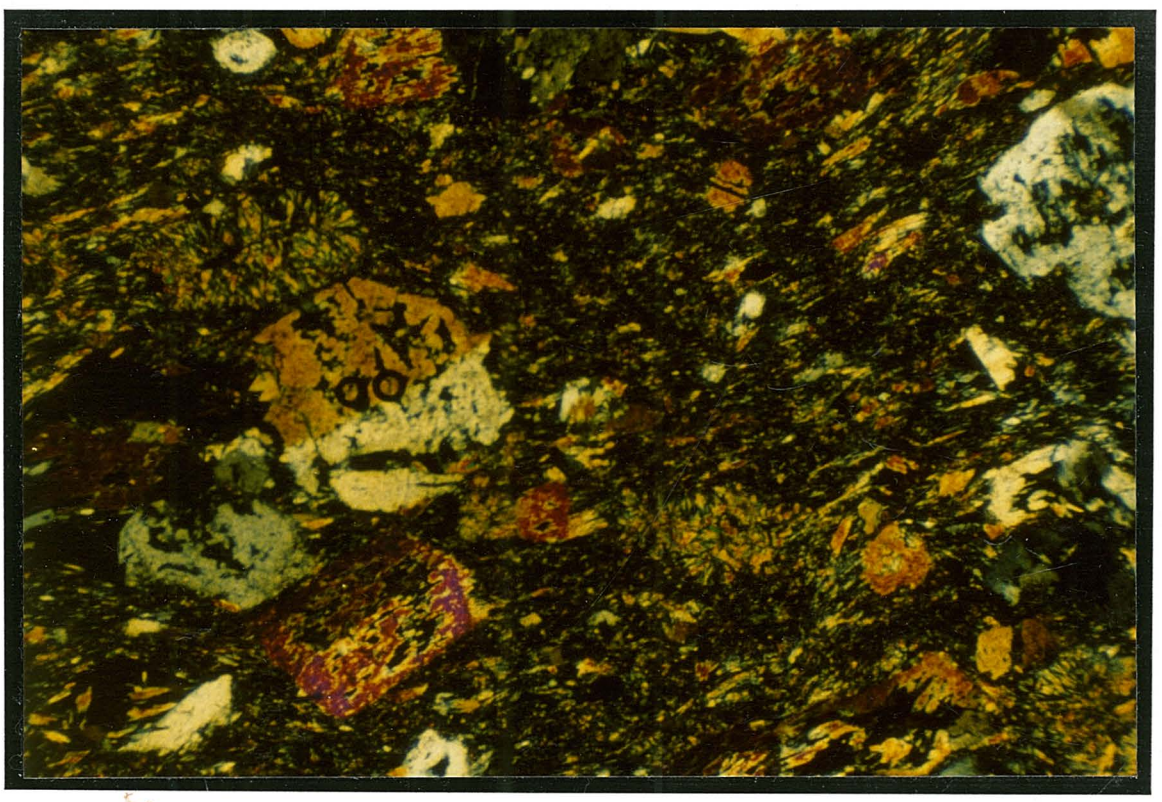

FIGURE 4-2. Large actinolite blastoporphs in a fine grained matrix. Sample (58999), field of view 7.5 mm.

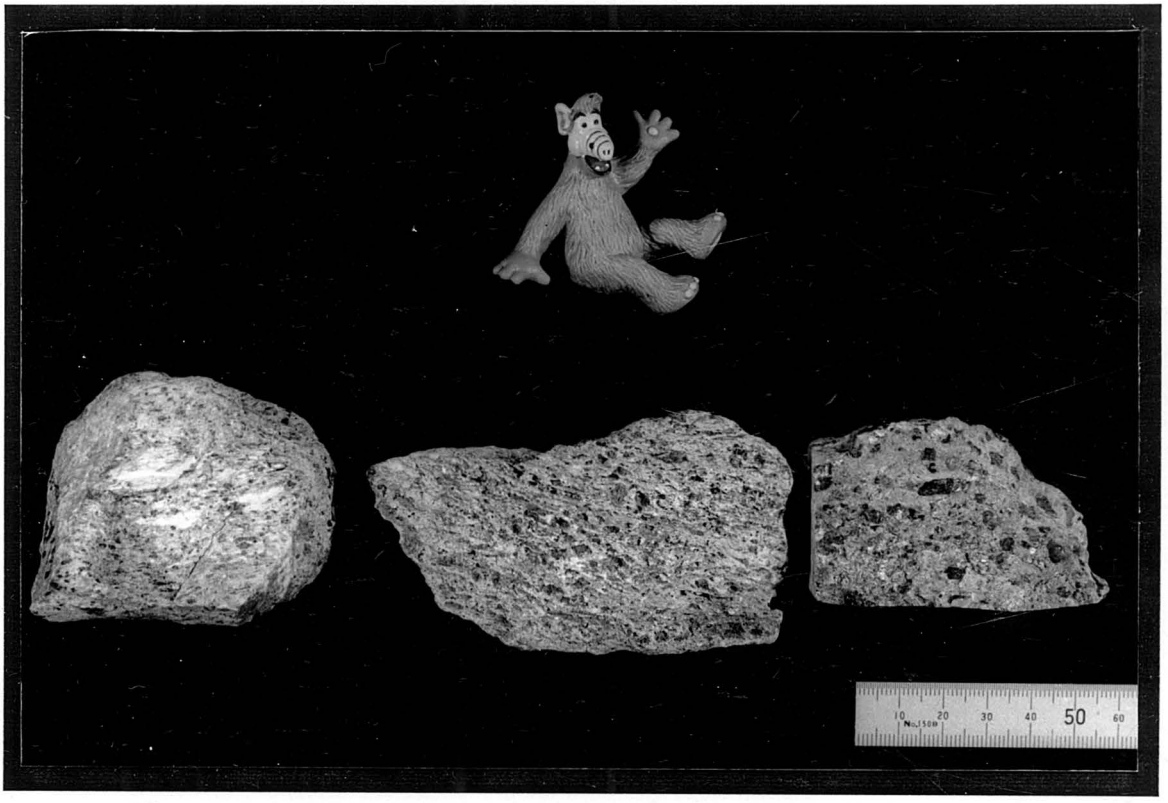

FIGURE 4-3. Varying degrees of deformation in the SF shown by samples 59012, 59013, 59014 (from right to left), where actinolite blastoporphs have been progressively sheared into the plane of foliation.

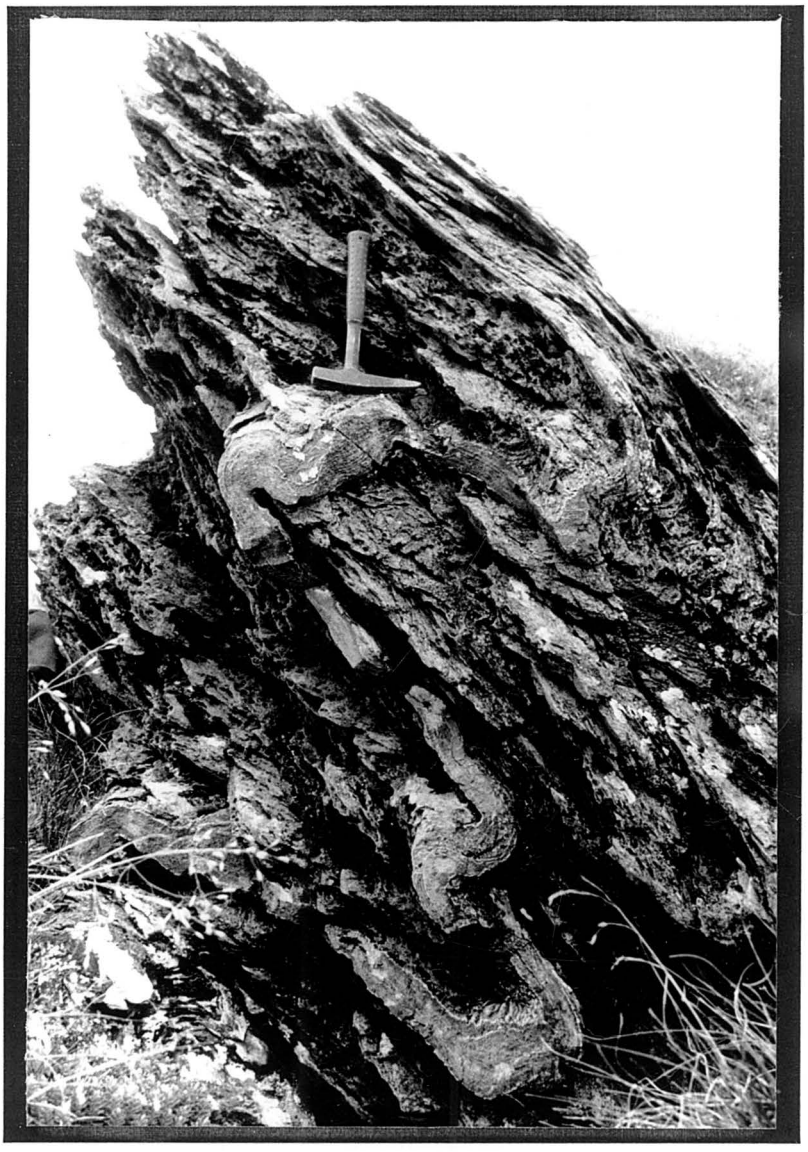

FIGURE 4-4. Small amplitude, asymmetric similar type folds and well developed axial plane schistosity in member m_1. Hammer for scale.

FIGURE 4-5. Limb of a large amplitude fold of indeterminate type in member m_1, note pack for scale. Observation of folds of this scale is rare probably due to orientation of the folds with respect to topography.

FIGURE 4-6. The characteristic "woody" appearance of member m_2 developed by the fine quartz segregations. Note discordant pencil for scale.

FIGURE 4-7. Tight, asymmetric folding style typical of member m_2. Note also the discordant discontinuous quartz veins. Pencil for scale.

FIGURE 4-8. Small scale tight symmetric and ptygmatic folding of member m_3. Hammer for scale.

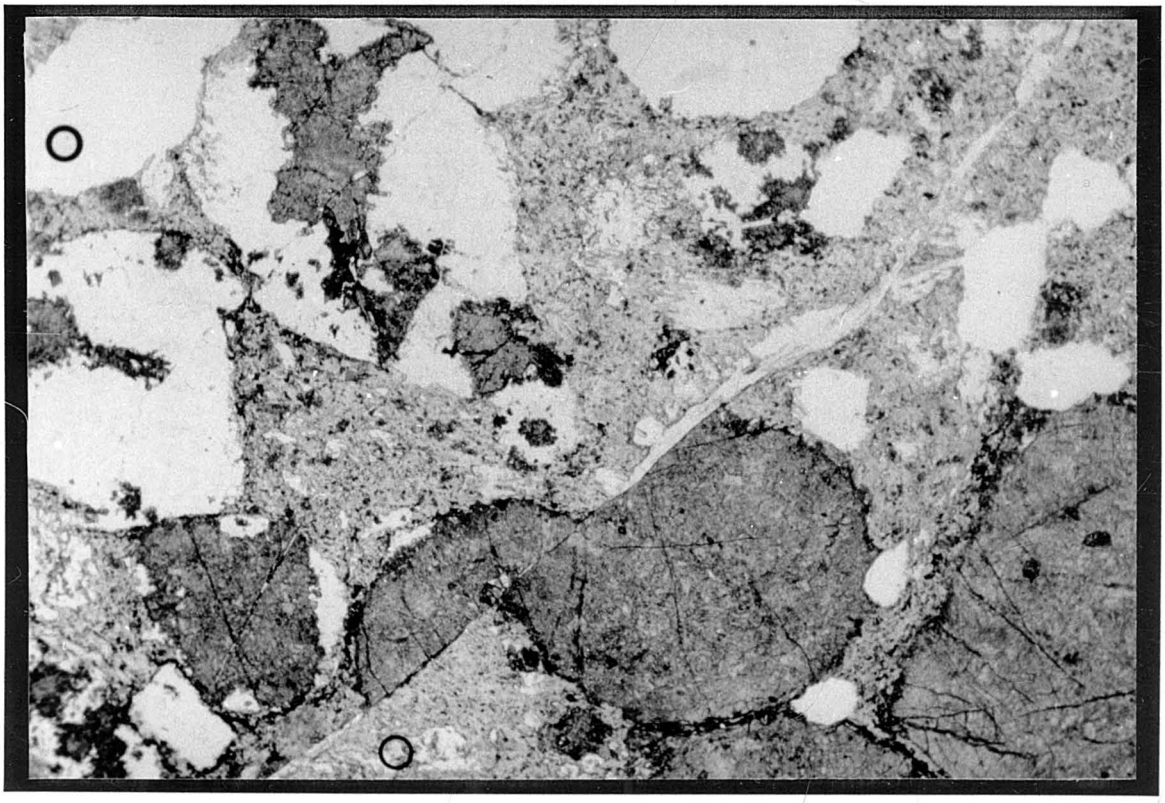

FIGURE 4-9. Epidote and albite filled spheroids in member m_5 which may represent an original variolitic or amygdaloidal structure. Sample 59001, plain light, field of view 7.5 mm.

FIGURE 4-10. Oblique aerial photograph looking southwest taken from ≈1 200 m at about GR 100404. The Wilmot Fault with a distinctive topographic expression due to recent movement is visible to the left of the "Twin Lakes" in the mid-ground. The movement sense is up on the east and the scarp is approximately 3 to 6 m high. Steeply east dipping schist of unit m_6 west of the trace in contrast with the more massive Twin Lakes Trondhjemite to the east. Mt.'s Tutoko and Madeline in the background.

FIGURE 4-11. Typical outcrop exposure of the Hokuri Intrusives member. The injections are generally large (0.5 to 1 m) and coherent in any single exposure but the member is disrupted internally so that there is no pervasive grain. Field assistant is approximately 1.7 m.

Western Formational Contact - Skippers Fault with shear zone 2 m wide. Both Slip Hill Granodiorite and Hokuri Intrusives have a well developed cataclastic foliation approaching contact.

Hokuri Intrusives (HI) - A complex of greenschist facies dikes or sills (original orientation uncertain), making up nearly the whole of the outcrop (fig. 4-11). The injections are coarse grained, blastoporphyritic rocks composed almost completely of large 1 to 2 cm actinolite blastoporphs (after pyroxene) or a massive, fine grained aphyric type. Attitudes of the intrusives are erratic with many being broken into intrusion breccias - angular blocks of one rock type floating in the other - within the larger injections. Well preserved chill margins are preserved on some dikes. Size of the intrusions ranges from <2 cm to greater than 2 m with the coarse blastoporphyritic type tending toward the larger and the aphyric toward the smaller ends of the scale. Some of the injections are extremely coarse with large megacrysts and xenoliths choking the conduit (fig. 4-12). Locally, a massive fine grained rock type is found as discontinuous screens and may have been a basaltic tuff or tuffaceous host rock.

Contact - Fault with shear zone gradational to both members.

Lone Stag Meta-Ultramafic Complex (LSUC) - Two small separated composite bodies of rocks of ultramafic protolithologies bounded by shear zones. Within these boundaries internal disruption is constrained to local 1 to 2 m wide deformation zones commonly with serpentine which may be relict zones of protoclasis. Rock types include megacrystic meta-pyroxenite, coarse grained meta-pyroxenite, meta-gabbro and serpentinised dunite and olivine pyroxenite with relict pyroxene. An original layered structure has been preserved (fig. 4-13) with stratification defined by alternating concentrations of what used to be plagioclase (now sericite, albite and epidote) and "knobby" actinolite (after pyroxene). The average attitude is 290,45S with local undulation possibly due to original magmatic deformation and some disruption due to small displacements along the internal shear zones. These features are best displayed in the area of "Black Rock Bowl" (GR 043369).

Cross cutting dikes 2 cm to 1 m in width of two types occur within the layered rocks. One is green-grey, very fine grained, massive and conspicuous in outcrop by a different concentration/type of lichen cover. These may have been residual liquids from the crystallisation of the layered rocks or primary magma feeders to the crystallisation chambers. The other type is an albitite and may have originally been late stage plagiogranite magmatic segregations. An attempt to date one of these by U-Pb (zircon) proved unsuccessful due to paucity of zircon.

Contact - Fault with shear zone gradational to both members (fig. 4-14).

Slabby Peak Schist (SPS) - Named after a knife edged peak of vertical slabs of predominantly fine grained, greyish green coloured schist (spot height 4250, GR 042365). Local discontinuous bands of actinolite porphyroblastic semi-schist from 10 to 30 cm occur within the fine grained schist.

The only observation of a surface discordant to the schistosity was made in the area east of "Slabby Peak" (informal name used by Nauman (1971, 1973) (GR 043365) and shown in figure 4-15. This surface, defined by fine quartz and feldspar laminations and mafic mineral concentrations, cuts sharply across the schistosity and is interpreted as relict sedimentary layering. Also in this area a single fine grained dike of granitoid was found intruding the schist nearly concordant to the foliation.

Eastern Formational Contact - Wilmot Fault with minor surface expression.

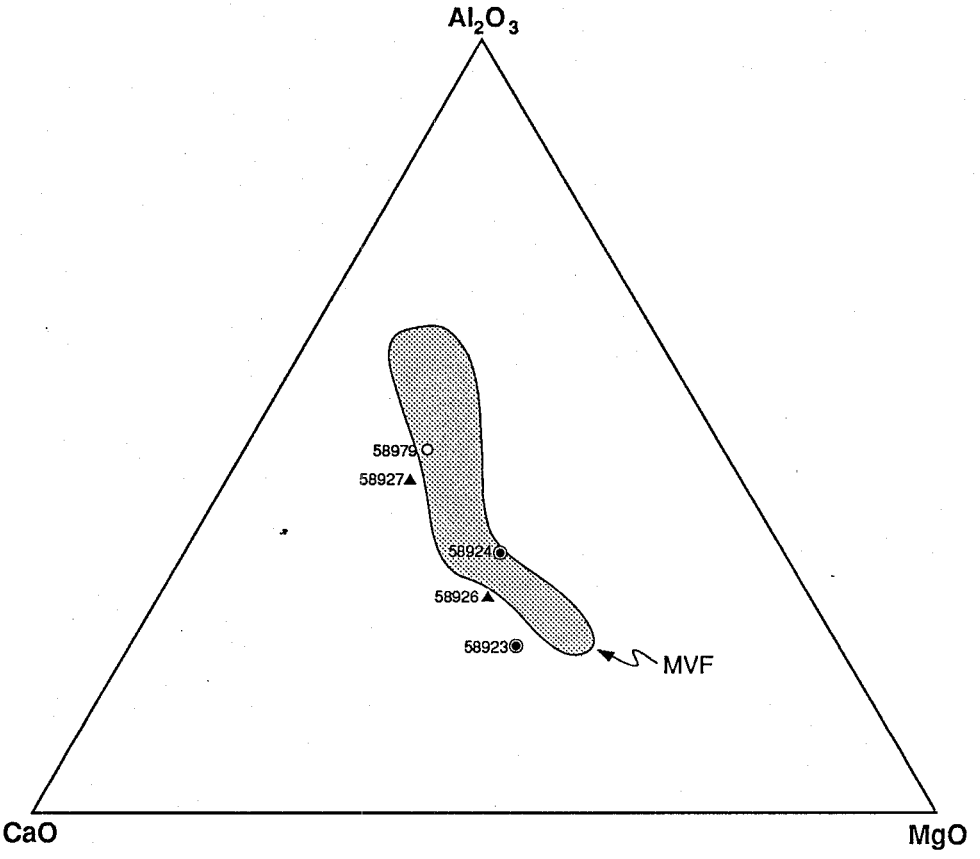

FIGURE 4-16 Whole rock analyses of the five rocks of the SF projected into the CAM composition plane with field of Mantle Volcanics Formation (MVF) intrusives shown.
● from LSUC, ▲ from HI, ○ from m_5.
The compositional overlap in samples from the LSUC and HI indicates the HI could have been derived from residual liquids of the LSUC. The similarity of compositions of the more evolved HI and the m_5 samples could be a result of the volcaniclastic portions of the SF having been derived from extrusive equivalents of some Hokuri Intrusives.

FIGURE 4-12. Exceptionally coarse grained injection of the HI.The large crystals with reflecting cleavage faces are actinolite. Below the Brunton pocket transit are cognate xenoliths up to 10 cm. The host rock is a massive, fine grained greenstone probably derived from a basaltic tuff.

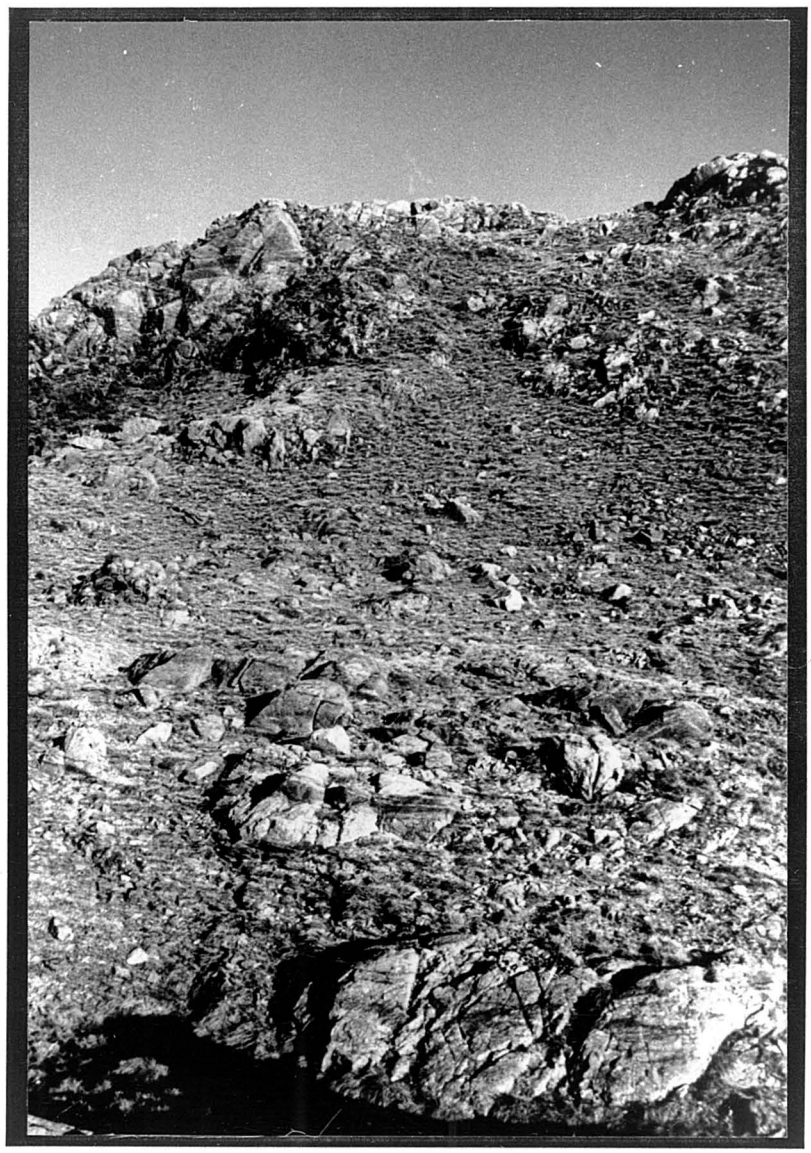

FIGURE 4-13. Lone Stag Ultramafic member in the area of "Black Rock Bowl" (GR 043369). The layering is sub-parallel to the skyline.

FIGURE 4-14. The contact of the SPS (resistant hill on the left with grey-green large slabby cleavage faces) and the LSUC (gentle ridge to right of reddish-grey colour) occurs at the break in slope of the mid-ground ridge. The view is to the south with hill 4260 (GR 045345) in background.

FIGURE 4-15. Mineralogical banding in Slabby Peak Schist member which may have been original sedimentary layering. Schistosity cleavage is parallel to the hammer and pencil.

FIGURE 4-17 Comparison of porphyry textures of the Mantle Volcanics Formation (left, sample 58956) and Skippers Formation (right, sample 59012). In the MVF sample the phenocrystic grains are clinopyroxene which often form cavities on exposed surfaces due to breakage along cleavage planes. In the Skippers Formation, blastoporphs are actinolite and stand in relief on weathered sufaces.

GEOCHEMISTRY

Whole rock major and trace element data for two samples each of the HI and LSUC and one of northern member m_5 are given in Appendix 1. In figure 4-16 the analyses are projected into the CAM composition plane with the field of Mantle Volcanics Formation (MVF, section 2) and trend of Plato terrane (Williams 1979) intrusives shown. The two samples from the LSUC have high chromium values commensurate with having been derived from primitive melts. The blasto-megacrystic dike from the HI (58926) shows a degree of evolution in the direction of the general trends defined by both the Plato terrane and MVF intrusives. The compositional overlap in samples from the LSUC and HI indicates the HI could have been derived from residual liquids of the LSUC. The similarity of compositions of the more evolved HI and the m_5 samples could be a result of the volcaniclastic portions of the SF having been derived from extrusive equivalents of some Hokuri Intrusives.

Although the degree of mineralogical reconstitution makes comparisons based on major element chemistry rather tenuous, the analyses of the SF samples are similar to one or more of the samples from the Mantle Volcanics Formation (fig. 4-16 and compare values in Appendix 1). Especially notable are the low concentrations of TiO_2 and alkalies and high normative anorthite contents, a distinctive characteristic of many of the rocks of the MVF. Whether the similarity is artificial or been enhanced by removal of mobile elements such as the alkalis is unknown.

CONCLUSIONS

The Skippers Formation includes a crustal sequence of ultramafic to mafic cumulates (LSUC), mid-level intrusive rocks (HI) and meta-sediments of basic tuffaceous parentage (SPS and northern members). Taken together, and assuming they are all related, the members of the SF are inferred to be scraps of dismembered island-arc basement. The tectonic position of this basement is unclear, it could have been in either a back- or fore-arc setting. The LSUC and HI show no evidence of penetrative deformation suggesting metamorphism under hydrothermal conditions. The less competent sediments making up the the bulk of the SPS and northern members and at one time lying atop the crustal rocks, have been severely deformed, possibly during a collision event or, if in the fore-arc, contemporaneous with subduction.

Possible genetic links between the SF and the MVF are:

1- the actinolite blastoporphyritic rocks found in the Skippers Formation, which are similar in texture (fig. 4-17) to the abundant clinopyroxene phyric rocks which characterise the MVF to the east and

2- both formations are basaltic in character with apparently similar chemistry.

Deformation of the SF is most severe in the SPS and northern members, where the protolith is predominantly of sedimentary origin. Well developed schistosity, foliation, folding of a variety of types and scales and zones of ductile deformation is characteristic of these units. This is in marked contrast to the essentially undeformed MVF which has no pervasive metamorphic fabric. The metamorphic grades of the two Formations are also quite different. Actinolite amphibole is ubiquitous in the SF with only local preservation of clinopyroxene relics. In the MVF, actinolite is only incipiently developed as an alteration phase of clinopyroxene with prehnite, and locally pumpellyite present. The two Formations then have very different metamorphic and tectonic histories prior to suturing by the Twin Lakes Trondhjemite. The lack of age determination of the SF makes it impossible to test further their consanguinity.

If the SF was part of the fore-arc wedge of the Brook Street Terrane and the MVF and SF had not changed their relative positions before being sutured, the indication is of a subduction zone which dipped eastward with respect to their present positioning. Considering the complex tectonic history of the Gondwanaland margin from the time of "docking" of the Permian terranes to the present and the tectonic movements which must have taken place before the "docking" and during breakup, it is impossible to determine the exact rôle played by the Skippers Formation without much more evidence.

SLIP HILL INTRUSIVES
and
MOUNT WEBB GNEISS

SLIP HILL INTRUSIVES

Two tabular plutonic bodies of quartz-diorite and granodiorite are exposed in the western part of the Skippers Range between trig stations H (24'), and Mt. Pyke No. 2 (3993') (see map in pocket). The names Slip Hill Diorite[1] (SHD) and Slip Hill Granodiorite[1] (SHG) are proposed here for the western and eastern bodies respectively. The name Slip Hill Intrusives is used to refer to both bodies. The names are taken from trig station Slip Hill (3941', GR 069479). The type locality for the SHD is at GR 067444 (59010) and for the SHG at GR 076457 (59011). Neither pluton shows appreciable compositional change along strike, are generally of massive, hypidiomorphic granular texture but have a well developed foliation near and parallel to their contacts. Greenschist facies assemblages occur throughout both bodies.

The SHD is in fault contact on the east with the SHG. The contact with the Mount Webb Gneiss (MWG) to the west is intrusive. Epipheses of dioritic rock, both concordant and discordant, have been observed within the MWG at a number of locations near the contact. The Slip Hill Granodiorite (SHG) is in fault contact on the east with the Skippers Formation and the west with the SHD. Both the bodies were mapped as Darran Diorite by Wood (1962), Mutch (1964) and Mutch and McKellar (1965). These authors made no distinction between them. Nauman mapped the SHD as Darran Complex and the SHG as Slabby Peak Schist member of the Skippers Formation. The SHD yields a slightly discordant U/Pb zircon age of 226 Ma for the fine fraction (49142; unpublished data, D.L. Kimbrough pers. comm. 1984, Appendix 6). Samples collected for preliminary oxygen isotope investigation have different isotope ratios (6.09±0.1‰ for the SHD and 8.05±0.2‰ ($\delta\ ^{18}O_{SMOW}$) for the SHG; P. Blattner pers. comm. 1984, Appendix 6). These ratios are in the normal range for rocks of these compositions and the different values are most likely a result of the greater concentration of quartz and alkali feldspar in the SHG.

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[1] Classifications based on a modification of the scheme of Streckeisen (1976).

Petrography

Slip Hill (quartz-) Diorite

Plagioclase - ≈55%

Cloudy, highly altered, rectangular ≈2.5 by 1 mm euhedral to sub-hedral tabular crystals with alteration phases defining relict zoning. Alteration phases consist of albite, quartz, muscovite, epidote and possibly zoisite. Grains locally bent and strained. Completely albitized.

Alkali feldspar - ≈<1%

Quartz - ≈15%

Interstitial to plagioclase and mafics. Many grains contain inclusions in sealed fractures with local larger inclusions of apatite. Some recrystallised with a preferred crystallographic orientation.

Hornblende - ≈15%

Some grains twinned. Pleochroism α light green yellow, γ dark green, β light green. Local glomeroporphyritic clots altering to chlorite, actinolite, epidote, titanite.

Chlorite (after biotite) - ≈15%

Anomalous blue interference colour locally interlayered with small amounts of biotite. Inclusions of epidote, sagenitic ?rutile needles and very fine garnet.

Accessories

Apatite

Titanite as scattered euhedral to sub-hedral grains.

Zircon

Slip Hill Granodiorite

Descriptions similar to those for SHD

Plagioclase - ≈40%

Alkali feldspar - ≈15%

Interstitial to plagioclase and mafics some grains strained. Various types of myrmekitic textures with quartz. Some sealed fractures with inclusions.

Quartz - ≈25%

Hornblende - ≈10%

Chlorite (after biotite) - ≈10%

Accessories

Apatite

Titanite may be as much as 1%.

Zircon

Interpretation and Correlation

Both these bodies are similar in mineralogy and alteration and only really differ in their mode. It is inferred then that they are related, the granodiorite being more evolved. The SHD is petrographically similar to the Mistake Diorite of Williams (1975, 1978) particularly with respect to the abundant occurrence of euhedral titanite and sagenitic rutile within chlorite (after biotite). They are also similar in terms of age (D.L. Kimbrough pers. comm. 1984, Appendix 6), chemistry (see table 5-1) and structural position relative to correlative strata (the MVF and Gondor Formation of the Plato terrane).

TABLE 5-1. Comparison of whole rock chemistry between Mistake Diorite and Slip Hill Diorite. Analyses normalised anhydrous with $Fe^{2+}/\Sigma Fe = 0.85$. Mistake Diorite data fromWilliams (1975).

OU Number	35074	35052	35032	35072	58922
	Mistake Diorite				SHD
SiO_2	58.47	58.31	57.04	55.75	61.17
TiO_2	1.14	1.11	1.29	1.26	0.88
Al_2O_3	15.89	17.15	17.20	16.82	17.55
FeO	6.05	5.73	6.67	6.85	5.30
Fe_2O_3	2.37	2.25	2.61	2.69	1.04
MnO	0.10	0.11	0.14	0.11	0.11
MgO	3.51	3.45	3.26	4.44	2.70
CaO	5.81	5.87	5.79	6.16	5.40
Na_2O	3.75	4.24	3.63	4.06	3.48
K_2O	2.66	1.50	2.09	1.55	2.19
P_2O_5	0.27	0.28	0.26	0.31	0.17

MOUNT WEBB GNEISS

The Mount Webb Gneiss (MWG; new name) is proposed here for a highly deformed assemblage of amphibolite facies schists and gneisses and amphibolite gniesses. The name is taken from trig station Mt. Webb (3800') (see map in pocket) and the type locality designated as that about the small hill at GR 065461. The unit was not recognised by Grindley (1958) and was previously mapped by Wood (1962), Mutch (1964) and Mutch and McKellar (1965) as Thurso Formation. Wood (1962) correlated the Thurso Formation with parts of the Cambrian of Nelson. A number of good exposures of the unit can be found in the streams and slips up from the Demon Trail south of Hokuri Hut.

The unit consists predominantly psammitic meta-sedimentary and meta-igneous rocks of amphibolite facies metamorphic grade. In general a well developed, pervasive and vertical to steeply dipping foliation is present defined by lepidoblastic micas and quartzo-feldspathic banding. Locally, the foliation is isoclinally folded on outcrop (amplitude 10 to 30 cm) and thin section (amplitude 1 to 3 cm) scales and mylonitic and migmatitic textures are not uncommon. Intrusive epipheses of the SHD cross-cutting the foliation indicate an early or pre-Triassic age for the deformation. Detailed investigation of

the unit was not undertaken for this thesis; descriptions being based predominantly on field identification. Four selected specimens are described briefly below.

59014

Biotite semi-schist (meta-psammite).

Weak foliation and schistosity. Grain size of quartz and feldspar <1 to 3 mm with biotite as 1 to 2 mm plates. Thin bands of biotite (1 mm) and and quartz-feldspar (<1 to 2 mm). Porphyroclasts of quartz-feldspar to 1 cm.

59015

Muscovite-biotite schist (meta-psammite).

Well developed foliation and schistosity. Grain size of quartz-feldspar <0.5 mm, mica plates up to 1 mm. Thin bands of biotite (<0.5 mm) and quartz-feldspar (1 to 2 mm). Foliation is tightly folded at an amplitude and wavelength of 1 to 2 cm giving rise to two cleavages which cause the rock to break in a rhomboidal shape.

59016

Biotite-hornblende amphibolite (basic ?meta-igneous)

Well developed lineation of hornblende crystal aggregates 0.5 to 1 cm in length. Deep red-brown pleochroic biotite plates are elongated parallel to the hornblende and define a weak foliation and schistosity. Grain size averages 0.5 mm.

59017

Biotite schist (meta-psammite) from near contact with SHD

Well developed foliation and poor schistosity and mineralogical segregation. Grain size from 0.15 to 1 mm in parallel concentrated coarse and fine layers. Small scale isoclinal folds of 2 to 3 cm amplitude. Small amounts of chlorite are interleaved with biotite indicative of retrogression. Elongated and comminuted K-feldspar grains are common in the coarser layers.

The western contact of the MWG is the Alpine Fault and although the recent trace is spectacularly exposed, no exposure containing MWG was observed near the fault. The eastern contact with the Slip Hill Diorite is well exposed above bush line and is intrusive. The SHD and MWG are strongly foliated parallel to their contact where the MWG incompletely retrograded to greenschist facies assemblages. Locally, the SHD is weakly foliated and gneissose near the contact and thin bands of it interlayered with schists of the MWG (fig. 5-1). At these contact exposures the schist appears to have been thermally metamorphosed retaining its foliation but losing much of its schistose cleavage. Two stream expo-

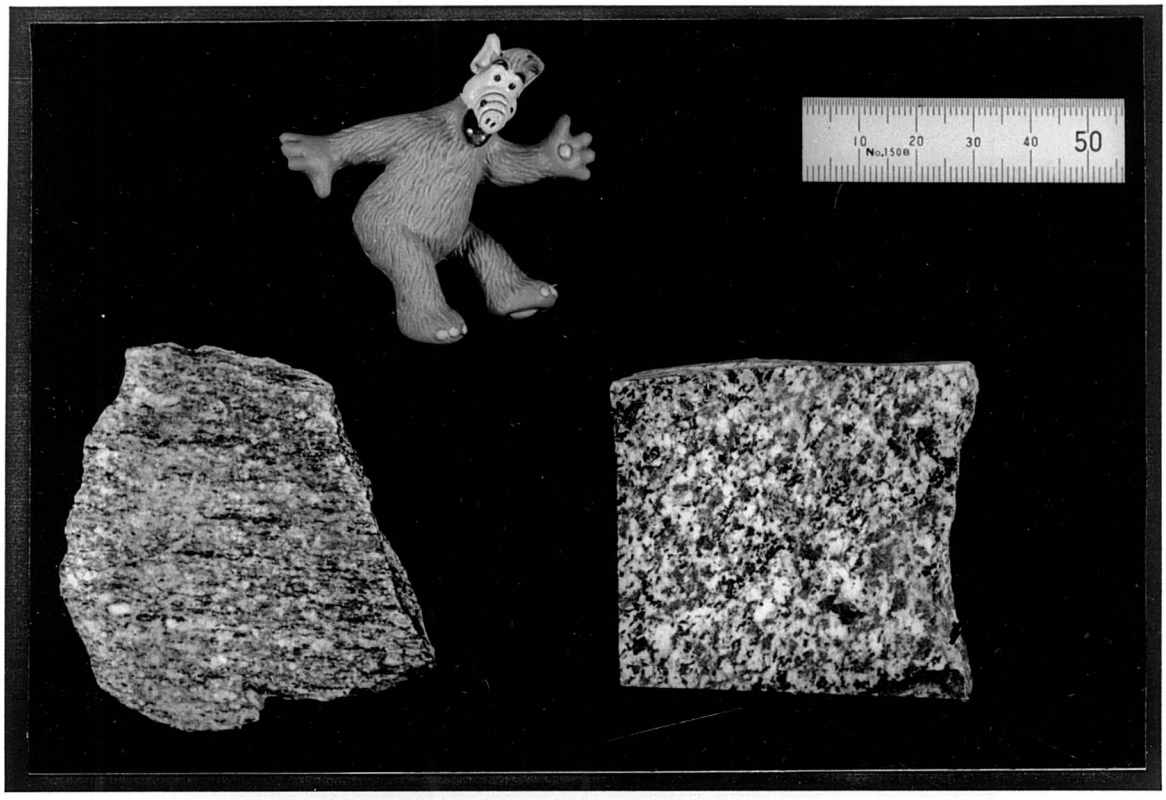


FIGURE 5-1. Photograph of samples 59018 (left) and 59019 (right) showing typical textures of foliated and massive SHD.

FIGURE 5-2. Photograph of the contact of the strongly foliated MWG on the left and weakly foliated SHD on the right. At this contact (GR 072477) thin 1 cm concordant streaks of SHD occur in the MWG.

sures (GR 015395, GR 037417) have epipheses of massive SHD cross-cutting steeply dipping MWG foliation.

The MWG was not mapped as Thurso Formation here for a number of reasons:

1- The MWG bears little resemblance to the Thurso Formation (as mapped by Wood (1962)) exposed around Poison Bay (J.Y. Bradshaw pers. comm 1983).

2- Bradshaw (1985) questions the validity of the Thurso Formation as a unit based on his observations around Poison Bay. He instead maps gneissic rocks west of and in fault contact with the Western Fiordland Orthogneiss as "Jagged Gneiss".

3- The intrusive contact with the SHD, the existence of biotite gneiss and schist with post-tectonic intrusions west of Brook Street Terrane rocks in the Dunton Range (Lindsay 1980), the SHD's similarity to the Mistake Diorite and the occurrence of highly deformed gneissic mylonites in the Mistake Fault zone within the Mistake Diorite (Williams 1975, 1978), lend some weight to the MWG not necessarily correlating with the Thurso Formation to the south.

4- No attempt was made in this study to check on similarities of the MWG with rocks on the west side of Lake McKerrow across the postulated Glade-Darran Fault (D.G. Bishop pers. comm.) which where mapped elsewhere separates "Fiordland Complex" type rocks from eastern province terranes.

Although subsequent investigation may show the MWG to be correlative with rock units occurring further south along the west coast of Fiordland, in light of the above information, it is my view that mapping the MWG as Thurso Formation at this time is misleading and may well be incorrect.

SUMMARY AND SYNTHESIS

LITHOLOGIC UNITS OF THE SKIPPERS RANGE

The Skippers Range comprises five major, distinctive lithologic blocks: the Mantle Volcanics Formation (Early Permian, faunal age), Skippers Formation (pre-Middle Triassic, relative age), Mt. Webb Gneiss (pre-Triassic, relative age) and two separated but probably related plutonic bodies the Slip Hill Intrusives (Early-Mid Triassic, radiometric age) and Twin Lakes Trondhjemite (Early-Mid Triassic, by association). A probably fault bounded local conglomeratic unit of unknown age occurs along the Wilmot Fault in the south. The Slip Hill Intrusives, Twin lakes Trondhjemite and Skippers Formation all contain greenschist facies assemblages. The Mt. Webb Gneiss contains amphibolite facies assemblages and the Mantle Volcanics Formation contains a sub-greenschist facies assemblage including prehnite and locally pumpellyite.

The Mantle Volcanics Formation (Nauman 1973) represents a single proximal facies greater than 1300 m thick of marine pyroclastic and epiclastic volcanogenic sediments deposited by debris-flow and high-density turbidites on the flanks of an active and at least partially emergent ankaramitic island-arc. The sequence is composed predominantly of coarse to very coarse tuffaceous breccias and tuffaceous sandstones intruded by an extensive co-genetic suite of tholeiitic dikes and sills making up greater than 30% of the outcrop. Sediment clasts are lithics, up to a metre or more in size in the breccias and similar to associated intrusive lithologies, and crystals of clinopyroxene and plagioclase. The Mantle Volcanics Formation dips moderately southwest and is nowhere overturned. Local variation in attitude may be due to detachment and rotation of sediment blocks between the dikes but probably represents, at least in part, original local depositional variation. A diverse Early Permian fauna discovered and collected during this investigation includes the first reported occurrence of the large bivalve Eurydesmidae. This fauna has been correlated by Begg and Ballard (1985, 1989) with other faunas from Lower Permian volcanogenic rocks of the South Island and sedimentary sequences in Australia.

The intrusive rocks of the Mantle Volcanics Formation are characteristically clinopyroxene phyric and span a continuous range from high MgO to high Al_2O_3 tholeiitic basalts which have been derived by fractionation of olivine and clinopyroxene from primary parental melts. These primary melts are locally represented in the intrusive suite and are high in MgO, Cr, Ni and low in incompatible trace elements, Ti and alkalis. Large degree partial melting of a refractory mantle source and crystallisation without significant fractionation while enroute to the surface and high crustal levels can account for the primitive and often strongly phenocrystic rocks. Reported occurrences of rocks similar in chemistry and petrography from modern island-arcs (for example New Georgia, Solomons

Islands; Merelava, Vanuatu) often coincide with areas of tectonic complexity usually involving the subduction of linear topographic features (e.g. ridges and transform faults) on the underthrust slab. Subduction of these features may lead to deep rifting and fracturing in the fore-arc to provide an unencumbered pathway for primary melts to ascend to the surface.

The Mantle Volcanics Formation is part of the Brook Street Terrane (see discussion below), a discontinuous belt of Permian island-arc derived volcanogenic sediments, lavas and intrusives which are characteristically strongly clinopyroxene phyric and distributed along a roughly north-south trend on both sides of the Alpine Fault (fig. 1-1).

The Twin Lakes Trondhjemite (new name) is a tabular, composite plutonic body of predominantly trondhjemitic composition which in part separates the Mantle Volcanics and Skippers Formations. It is bounded on either side by splays of the Wilmot Fault which show significant post-glacial displacement. In the northern Skippers Range rafts and xenoliths of Mantle Volcanics Formation lithologies have been observed within it. Epipheses of the body have been found within the western margin of the Mantle Volcanics Formation and eastern margin of the Skippers Formation. It is possible the body was intruded along the Wilmot Fault and subsequent tectonic movements have continued to localise about its margins along this discontinuity.

The Skippers Formation (Wood 1962) is composed of three fault bounded units of different protolithic character well equilibrated to greenschist facies mineral assemblages. These are: an internally disrupted but undeformed layered meta-ultramafic complex (Lone Stag Meta-Ultramafic Complex) including dunite, clinopyroxenite and gabbro protolithologies with cross-cutting dikes of plagiogranite and aphyric, probably late stage, basalts; a crustal level dike/sill complex (Hokuri Intrusives) of basic, often strongly blastoporphyritic intrusive rocks which are probably related to the Lone Stag Meta-Ultramafic Complex; folded and deformed crystal rich tuffaceous sediments and probably some high level intrusives (Slabby Peak Schist and members m_{0-6}). Although their present arrangement is not in a ordered crustal sequence, taken together they represent scraps of island-arc basement and volcanogenic sedimentary cover.

Two tabular plutonic bodies have been given the names of Slip Hill Diorite and Slip Hill Granodiorite. They are separated by an un-named fault but most likely genetically related. The eastern body, the Slip Hill Granodiorite, is bounded to the east by the Skippers Fault. The Slip Hill Diorite on the west, is in intrusive contact with the Mt. Webb Gneiss. The Slip Hill Diorite gives a 226 Ma U/Pb zircon age (unpublished data; D.L. Kimbrough pers. comm. 1984, Appendix 6).

The Mt. Webb Gneiss (new name) is a highly deformed assemblage of locally garnet bearing, amphibolite facies schists and gniesses which lies between the Alpine Fault to the west and the Slip Hill Intrusives to the east. These were previously correlated with the

Thurso Formation mapped along the western coast of Fiordland by Wood (1962) but may instead be correlative with high grade metamorphic rocks found in association with Brook Street Terrane units to the south, east of Fiordland.

RELATIONSHIP OF THE SKIPPERS AND MANTLE VOLCANICS FORMATIONS

The spatial relationship of the Skippers and Mantle Volcanics Formations, their common basaltic chemistry and the characteristic occurrence of actinolite blastoporphyritic rocks in the Skippers Formation which were probably derived from previously clinopyroxene phyric sedimentary and intrusive protoliths, makes it tempting to suggest a strong link between them. If this is the case, the Skippers Formation should probably be included in the Brook Street Terrane (discussed below).

Mutch and McKellar (1965) considered the Skippers Formation "...lying along the western margin of the Key Summit Syncline is the slightly older, more metamorphosed equivalent of the Eglinton Volcanics and has in addition small pyroxenite and peridotite layered intrusions at its base." The "base" of the Mantle Volcanics Formation (Eglinton Volcanics) was inferred to be to the west based on the published account of continuity of the Key Summit Syncline and a conformable contact with the eastward younging Maitai Group to the east (Grindley 1958). The Mantle Volcanics Formation dips moderately southwest with its base to the east so it is unlikely that the Skippers Formation is a basal section of the Mantle Volcanics Formation.

The two formations have very different metamorphic and deformational histories. The Skippers Formation in its entirety contains well equilibrated greenschist facies assemblages. Albite, epidote, actinolite, chlorite, muscovite and titanite are common if not ubiquitous with the complete absence of prehnite and/or pumpellyite and calcic plagioclase. Relict clinopyroxene occurs only locally in meta-pyroxenites and peridotites. By comparison, in the Mantle Volcanics Formation, prehnite occurs as an incomplete alteration of calcic plagioclase and vein fillings and actinolite only as incipient alteration of clinopyroxene. Pumpellyite was reported by Nauman (1971, 1973) but is restricted to marginal areas of shearing and deformation. Many rocks of the Mantle Volcanics Formation also contain primary calcic plagioclase along with a metamorphic assemblage of albite, epidote, quartz and chlorite. Although it is difficult to place the Mantle Volcanics Formation in a well defined metamorphic facies, it is certainly subgreenschist in distinct contrast to the higher grade Skippers Formation.

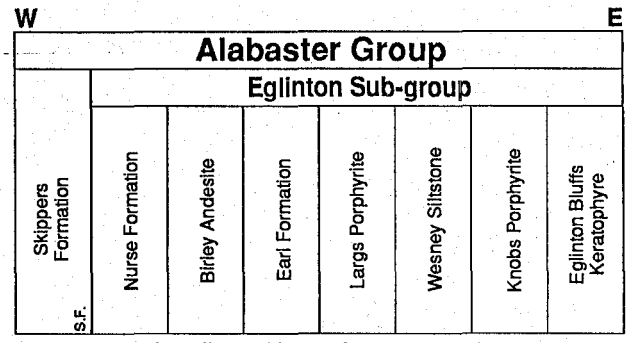
The Lone Stag Meta-Ultramafic Complex and Hokuri Intrusives members of the Skippers Formation are bounded by and locally contain zones of shear deformation. The northern ($m_{0\text{-}6}$) and the Slabby Peak Schist members, derived from predominantly volcaniclastic protoliths, are characterised by intense folding on a variety of scales from

micro- to meso-scopic and including tight isoclinal, asymmetric cylindrical and ptygmatic types. The Mantle Volcanics Formation shows no evidence of internal folding, shear zones or generation of any pervasive fabric although it is often sheared near the faulted marginal contacts.

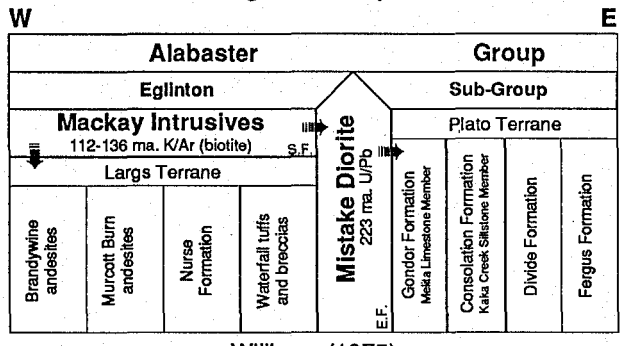
The age of the Skippers Formation is, at present, unknown. The Mantle Volcanics Formation has been shown by fossil evidence, to be Lower Permian. The Skippers Formation is limited in its exposure to the Skippers Range and correlatives have yet to be either discovered in association with, or determined to be distinct from, other remnants of the Brook Street Terrane (see figure 1-1). In light of the different metamorphic and deformational histories of the two Formations, the unknown age of the Skippers Formation and the absence of a Skippers Formation correlative in association with other remnants of the Brook Street Terrane, the genetic relationship of the Skippers Formation to the Brook Street Terrane is tenuous and unclear.

THE BROOK STREET TERRANE: A CRITICAL DISCUSSION

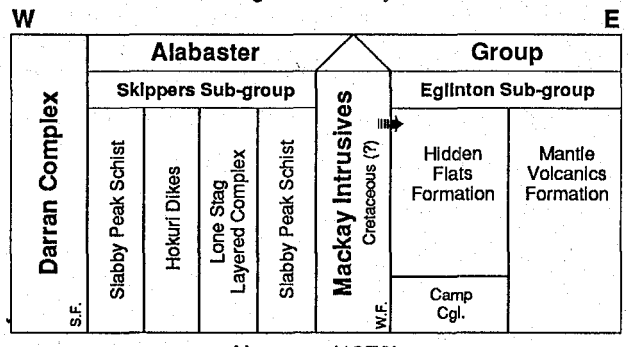
Figure 6-0 depicts schematically the contact relations of lithologic units in the Skippers Range and Eglinton Valley and how the nomenclature of these units has changed with time. The Mantle Volcanics Formation was originally included in the "EE" classification of Grindley (1958) as Eglinton Volcanics along with the more metamorphosed Skippers Formation, as introduced by Wood (1962), to the west. Landis and Waterhouse (1966) gave names to the numeric units EE_0-EE_6 of Grindley (1958) and defined the Alabaster Group to include the Eglinton Sub-Group and the Skippers Formation. Williams (1975, 1978) demonstrated the Eglinton Volcanics or Sub-Group in the Eglinton Valley to be composed of two distinct fault bounded terranes separated by the Mistake Diorite. The eastern Plato terrane consists of basaltic to andesitic volcanogenic, sparsely fossiliferous Lower Permian marine sediments intruded by abundant basaltic dikes many of ankaramitic affinity. The western Largs terrane is unfossiliferous, largely andesitic to dacitic, predominantly volcaniclastic with local massive andesite bodies and may be derived from a continental margin arc source. The Largs terrane also lacks the distinctive dike lithologies of the Plato terrane. Williams and Smith (1979) provided chemical evidence to indicate that the two terranes are unrelated by any simple tectonic or geochemical model and suggested the two terranes were either separate arcs or laterally separated accumulations within the same arc. On the basis of oxygen isotopic data, Blattner (1987) confirms the continental character of the Largs terrane and that the Plato and Largs are unrelated. He goes on to say that the Largs results require meteoric water in the hydrothermal system indicative of a high latitude (60°).



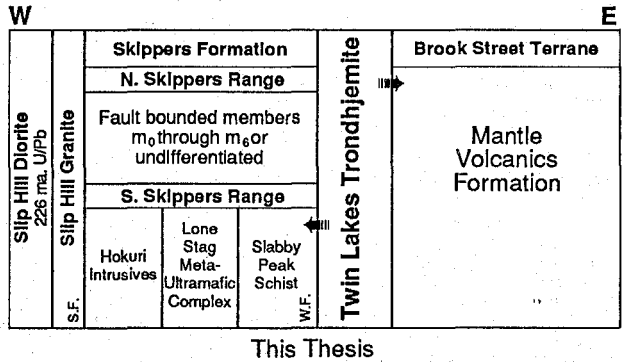
Landis and Waterhouse (1966)
modified after
Grindley (1958), Grindley et. al. (1959)
and Wood (1962)
Eglinton Valley.



Williams (1975)
Eglinton Valley



Nauman (1973)
southern Skippers Range
(modified after Table 1 to show map relationships)



This Thesis
Skippers Range

FIGURE 6-0. Schematic representations of the contact relationships and terminology used for rocks in the Eglinton Valley and Skippers Range by various workers.
S.F. = Skelmorlie Fault (Eglinton Valley), Skippers Fault (Skippers Range);
E.F. = Eglinton Fault; W.F. = Wilmot Fault
⇛ = intrusive contact (at least in part), | = fault contact

Paleomagnetic data from the Takitimu Group (also included in the "EE" classification of Grindley (1958)) suggest a mid-latitude (S 27.8°) position for these rocks during the early Permian (Haston et al. 1987). Preliminary paleomagnetic results from the Mantle Volcanics Formation show it to have a magnetic inclination indicative of 47° latitude and with a normal polar sense if in the southern hemisphere (Luyendyk pers. comm. 1987). This indicates that the Mantle Volcanics Formation and the sampled portion of the Takitimu Group were generated not only at different paleo-latitudes but at different times.

The term "Brook Street terrane" was coined by Blake et al. (1974) and Coombs et al. (1976) to refer to the volcanogenic sediments and associated intrusives of early to middle Permian age which included the Brook Street Volcanics, Eglinton Volcanics, Takitimu Group and Greenhills Group. Together these were interpreted as representing a single volcanic arc active in the Permian and possibly the source for volcanic detritus in the flanking Maitai and Murihiku terranes. The first attempt at defining terranes in New Zealand in the sense of accretionary blocks was done by Howell (1980). He included in the "Hokonui Ensimatic Arc Terrane" the "...Takitimu, Skippers and Eglinton Volcanics...", as well as the Dun Mountain ophiolite belt and Murihiku and Maitai strata, fostering the idea of a single, though inhomogeneous, arc complex. A provisional tectono-stratigraphic terrane map of the South Island was produced by Bishop et al. (1985) which took into account much unpublished data and discussion and defined the Brook Street-Murihiku Terrane without explicit mention of any formational units, but these are implied based on the knowledge of the previous definitions. This definition is basically a combination of the two terranes named in Coombs et al. (1976) based on published accounts of stratigraphic continuity between the Takitimu and Murihiku Groups (Wood 1962) which has since been discounted (Landis et al. 1987). Additionally, Frost and Coombs (1987) using Nd isotopes showed a continental arc signature for the Murihiku sediments and that these could not have been derived from the oceanic island arc Brook Street Terrane.

The term Brook Street as a geological unit was originally used by a number of authors to refer to a green, augite rich rock considered to be intrusive into Maitai Group sedimentary rocks (fide Johnston and Stevens 1985). The term "Brook Street Facies" was introduced by Wellman (1952) for the "...belt of basic volcanics...confined to the western side of the marginal syncline...continuous from D'Urville Island to the Alpine Fault...and then from the eastern side of the Alpine Fault at Lake McKerrow to the Takitimu Mountains". With the advent of the "terrane concept", all the Permian and some Mesozoic volcanically derived or related rock units were placed into the Brook Street Terrane. All of the sub-terranes of the Brook Street Terrane are fault bounded, laterally separated, with different faunal assemblages (Begg and Ballard 1989, Appendix 5), and some with very different deformation, metamorphic and paleomagnetic histories. By definition a terrane is a fault bounded entity of regional extent characterised by a geological history different from

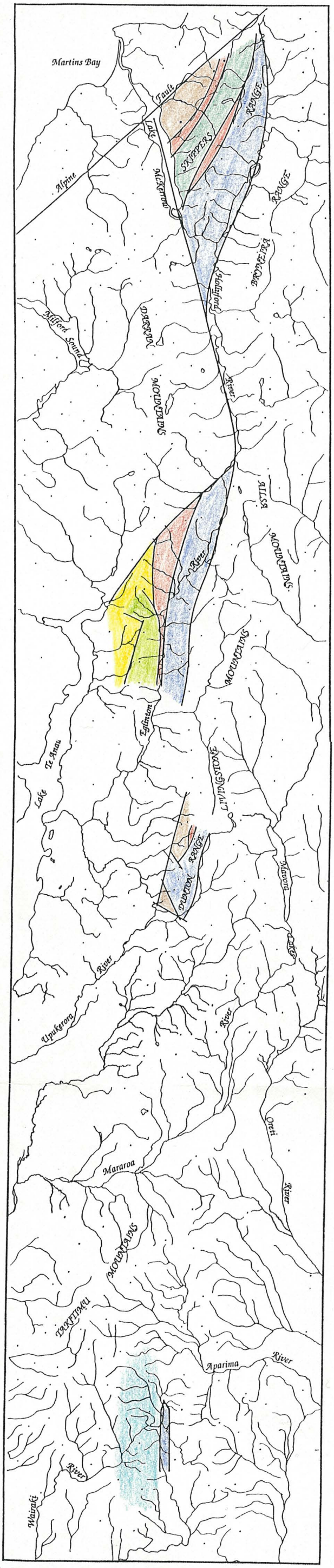
the histories of contiguous terranes (Howell et al. 1985). With respect to history prior to amalgamation to the Gondwanaland margin (and subsequent break-up), a distinctive and unifying feature of parts of the Brook Street Terrane is the occurrence of ankaramitic intrusive rocks emplaced into related volcaniclastic sediments. As such and in keeping with the original literature usage listed in Johnston and Stevens (1985), it is proposed here that the Brook Street Terrane be defined as only those Permian rock units which have ankaramitic intrusive rocks or can be shown to have originally been a sequence directly related to such units. This excludes from the current definition the Largs terrane of Williams (1975, 1978) and the Takitimu Group. The Skippers Formation which is sutured to the Mantle Volcanics Formation by the Twin Lakes Trondhjemite may be genetically related to the Mantle Volcanics Formation and so part of the Brook Street Terrane but the evidence for this to date is only circumstantial as the age of the Skippers Formation is undetermined and no correlative has been found in association with any other portion of the Terrane. This definition constrains the Brook Street Terrane to those rock units (Brook Street Volcanics, Mantle Volcanics Formation, Plato terrane, Eglinton Volcanics of the Dunton Range as mapped by Lindsay (1980), the "Caravan Formation" (Landis 1987), "Riverton Volcanics" (MacFarlane 1973) and probably the Greenhills Group and ultramafic complex; see figure 1 1 and 6-1) which were part of a volcanic island arc complex characterised by ankaramitic volcanism in the Early Permian.

RELATIONSHIPS CONSTRAINED BY INTRUSIVE ROCKS OF THE SKIPPERS RANGE AND ELSEWHERE IN THE BROOK STREET TERRANE SOUTH OF THE ALPINE FAULT

The MacKay Intrusives were defined by Grindley (1958) the name given to "...medium to coarse-grained igneous rocks which intrude the Eglinton Volcanics in the Eglinton Valley." Nauman (1973) proposed an expansion of the name to include "...all those medium and coarse-grained crystalline rocks which intrude the Eglinton Sub-Group." to take in intrusive rocks of similar structural position in the Skippers Range. Williams (1975) showed the MacKay Intrusives in the Eglinton Valley to made up of a number of mappable plutonic suites often with a range of rock types and including a discrete body he named the Mistake Diorite. It is this pluton that effectively separates the Plato and Largs volcanogenic terranes and is intrusive into the Early Permian Gondor Formation of the Plato. The MacKay Intrusives were suggested to be consanguineous by Williams (1975) and Williams and Harper (1978) but subsequent U/Pb (zircon) dating by Kimbrough (unpublished data) has yielded ages clustering in the latest Jurassic from plutons which lie west of the Early-Mid Triassic Mistake Diorite. The MacKay Intrusives therefore probably record two different tectono-magmatic events. The record of these events may be superposed in cross-cutting intrusive bodies or separated by an as yet undiscovered tectonic break. Both the Slip Hill Diorite and Mistake Diorite are of Early

Triassic age, petrographically similar and occur structurally west of rocks of the Brook Street Terrane, so it is not unlikely that these bodies are correlative. If they are, the intrusive relations of the Slip Hill Diorite with the Mt. Webb Gneiss and the Mistake Diorite with the Gondor Formation of the Plato terrane (Brook Street Terrane) indicate a spatial relationship of the Mt. Webb Gneiss and Brook Street Terrane rocks by at least Early Triassic. A unit of biotite gneiss mapped in the Dunton Range by Lindsay (1980) west of Brook Street Terrane rocks (see fig. 6-1) which may be correlative with the Mt. Webb Gneiss, contains epipheses of fine grained mafic and felsic and plutonic rock cross-cutting the foliation.

The intrusive relationships of the Twin Lakes Trondhjemite with the Skippers Formation and the Mantle Volcanics Formation provide a relative minimum age constraint on the spatial association of these two units. It is possible that the Twin Lakes Trondhjemite may be broadly consanguineous with the Mistake Diorite-Slip Hill Diorite magmatic event based on its pre-Wilmot Fault intrusive relationship with the Mantle Volcanics Formation and structural position west of the Slip Hill Diorite. If this is so then a spatial association of the Mantle Volcanics Formation, and the Skippers Formation and Mt. Webb Gneiss existed by at least the Early Triassic. In a very simplistic scenario, the Mt. Webb Gneiss may be a scrap of continental crust which was deformed during the collision of the Brook Street Terrane island-arc. In the collision a portion of the fore-arc basement and arc derived sediments (Skippers Formation) were entrapped between the continent and the arc itself. Intrusion of granitoid rocks along the faulted boundaries between these tectonic units sutured the units together. Subsequent tectonic movements and faulting along these discontinuities has obscured original relationships and disrupted and distributed the remnants along a presently north trending line south of the Alpine Fault.



Explanation

- Undifferentiated plutonic rocks of the MacKay Intrusives of known or inferred Jurassic age
- Mistake Diorite – Slip Hill Intrusives. Early to Mid Triassic and other plutonic rocks of inferred to be similar in age.
- Largs terrane. Volcanogenic rocks of unknown age shown to be unrelated to the Brook Street Terrane.
- Takitimu Group. Early Permian volcanogenic sediments and intrusives considered here to be unrelated to the Brook Street Terrane.
- Brook Street Terrane. Early Permian volcanogenic sediments and intrusives, characteristically clinopyroxene phyric.
- Skippers Formation. Ultramafic complex, intrusive dike/sill complex, deformed volcanogenic sediments. Age unknown.
- Highly deformed biotite schists and gneisses often with garnet. In the Dunton and Skippers Ranges this unit contains post-deformation epipheses of plutonic rock identifiable as Slip Hill Diorite in the Skippers Range.

FIGURE 6-1. Regional distribution of Permian volcanogenic, Mesozoic intrusive and high-grade metamorphic rocks of the Skippers Range, Eglinton Valley, Dunton Range and Takitimu Mountains.

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APPENDIX 1
WHOLE ROCK ANALYSES

Samples were prepared for X-ray fluorescence analysis by cutting 1 cm slabs from field samples which were trimmed to remove superficial weathering rinds. These slabs were cut into approximately 1 cm cubes using a hydraulic splitter with sharpened knife-edge jaws. Potential inter-sample contamination was reduced by cleaning the jaws thoroughly between samples and lining the splitter with plastic wrap to keep the split material contained. The cubes were crushed for approximately 15 seconds in a TEMA mill using tungsten carbide pucks. The mill was thoroughly cleaned between samples with hot water and alcohol, and pre-contaminated with a portion of the next sample. A jaw crusher was not used as previous experimentation showed significant iron contamination of samples prepared with it. The 1 cm cubes are easily crushed in the TEMA if care is taken in loading the mill. Due to the porphyritic nature of many of the samples, large amounts powder (up to 300 gm) for each sample were prepared.

Sample splits for major and trace element analysis were made using the cone and quarter method. Aliquots for replicate analyses were taken from a second split.

Fused glass disks were prepared for major element analysis from the powders after drying at 110°C for 24 hours to remove adsorbed volatiles. The fluxing agent was dried at 500°C for 1 hour then left to equilibrate to room temperature and humidity each day of fused disk manufacture. The flux was assayed for volatile weight loss before addition to each run of four samples. Rock powder was added to a weighed Pt-Au crucible to a tare weight of 0.40444 ±0.00005 gm. A tare weight of flux corrected for volatile content of 2.16667 ±0.0002 gm was added to the powder. Weighing was performed using a Mettler analytical balance. This mixture was then covered and fused in a furnace at 1100°C for 20 minutes, cooled to room temperature in a desiccator and re-weighed to obtain the reported loss-on-ignition (LOI) values. The fused glass was re-heated with a Meker burner, cast into disks and annealed at 100°C for 24 hours.

The loss-on-ignition (LOI) values for some samples are overly high indicating a small loss of material during the process, probably during cooling after fusion where contraction of the fused glass is rather violent. No attempt was made to check the LOI values using a separate loss-on-ignition technique (comparing weights of separate aliquots after ignition at 1 000°C) as the small gain in accuracy would contribute little to the overall conclusions gleaned from the bulk chemistry.

To reduce arithmetic errors during weighing a program was written for a Hewlett-Packard 41-C calculator to determine the various tare weights and LOI values.

Pressed powder pellets were used for trace element analysis made by further crushing the powders in a SPEX mill for 5 minutes, adding 5 ml of binding agent and compressing in a hydraulic press.

Analyses for major elements were performed either at the University of Canterbury using University of Otago standards or at the University of Otago. Unfortunately, the Na_2O values of some of the replicate samples analysed by Canterbury differ by as much as 3 weight percent. These errors seem to have been generated at random by problems with the counting equipment (S. Weaver, pers. comm.). Some of the affected samples have been re-analysed at O.U. and corrected, but even these values are suspect for Na_2O values less than about 2% as the calibration curve is heavily weighted toward high Na_2O standards.

Major element analyses have been re-calculated to an anhydrous form with $Fe^{3+}/Fe^{2+}=0.15$ for reasons suggested by Brooks (1976) but more consistent with current literature re-calculation schemes (Foden and Varne 1980; Basaltic Volcanism Study Project 1981) and determinations for low pressure fresh basalt glasses (Bryan et al. 1981). The normative values have been determined with this calculated iron oxidation ratio using a "tholeiitic norm" in which normative calculations are terminated at nepheline and corundum is not determined. This is obviously inadequate for the granitoid samples and small negative diopside values result.

Standard errors for the major elements have been calculated using 15 replicate analyses and are tabulated below.

Oxide	error	% error
SiO_2	0.01	1.18
TiO_2	0.02	1.83
Al_2O_3	0.01	1.43
FeO	0.01	1.41
Fe_2O_3	0.02	1.60
MnO	0.10	9.60
MgO	0.02	2.48
CaO	0.01	1.21
Na_2O	0.44	44.60
K_2O	0.17	16.64
P_2O_5	0.06	5.82

These have been calculated as:

$$\frac{\left| Oxide^1 - Oxide^2 \right|}{\left[\frac{Oxide^1 + Oxide^2}{2} \right]}$$

where the superscripts denote a sample and its replicate.

All trace element analyses were performed in-house. Some samples have trace elements reported as negative values. Although these elements probably have concentrations

above the detection limit, calibration curves were based on higher concentration standards, severely limiting accuracy at low concentrations.

Analyses of groundmass of porphyritic rocks to estimate liquid compositions were performed on polished thin sections using a JEOL JX-5A electron microprobe housed at the University of Otago. Each analysis represents an average of at least twenty analyses of 100 μ^2 areas selected at random and free of phenocrysts. The individual areas were analysed by rastering a <5 μ beam such that the area was scanned every 10 seconds. Spectrum collection was 100 seconds (real time) so that an area was scanned 10 times for each analysis. Machine operating parameters were as described in Appendix 2.

Whole rock major and trace element analyses.

OU Number	58937	58938	58939	58940
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #1	N. section #1	N. section #1	N. section #1
Description				
SiO_2	46.34	48.52	50.72	49.97
TiO_2	0.86	0.60	0.88	0.70
Al_2O_3	19.75	13.02	19.56	17.11
Fe_2O_3	10.88	11.46	11.98	10.30
MnO	0.19	0.20	0.18	0.05
MgO	5.01	9.81	5.21	6.65
CaO	10.20	11.72	10.42	11.23
Na_2O	2.53	1.14	3.19	1.70
K_2O	0.84	0.84	1.10	1.27
P_2O_5	0.11	0.11	0.17	0.12
LOI	3.70	2.82	2.52	2.12
Total	100.41	100.24	105.93	101.22
Anhydrous				
SiO_2	48.38	50.31	49.54	50.87
TiO_2	0.90	0.62	0.86	0.71
Al_2O_3	20.62	13.50	19.10	17.42
FeO	8.69	9.09	8.95	8.02
Fe_2O_3	1.70	1.78	1.76	1.57
MnO	0.20	0.21	0.18	0.05
MgO	5.23	10.17	5.09	6.77
CaO	10.65	12.15	10.18	11.43
Na_2O	2.64	1.18	3.12	1.73
K_2O	0.88	0.87	1.07	1.29
P_2O_5	0.11	0.11	0.17	0.12
Normative mineralogy				
q	0.00	0.00	0.00	0.30
or	5.18	5.14	6.34	7.63
ab	22.33	9.99	26.34	14.63
an	41.80	28.94	34.95	35.93
ne	0.00	0.00	0.00	0.00
di_{wo}	4.27	12.75	6.01	8.33
di_{en}	2.06	7.64	2.83	4.61
di_{fs}	2.14	4.42	3.11	3.39
hy_{en}	2.45	15.70	1.02	12.18
hy_{fs}	2.54	9.07	1.13	8.96
fo	5.92	1.32	6.14	0.00
fa	6.77	0.84	7.46	0.00
mt	2.48	2.59	2.55	2.29
il	1.71	1.18	1.64	1.36
ap	0.25	0.25	0.36	0.27
Trace elements (ppm)				
Sc	29	35	28	26
V	392	319	353	323
Cr	16	329	25	164
Ni	16	114	23	60
Ga	22	16	20	20
Rb	14	13	17	19
Sr	434	247	526	336
Y	19	17	18	19
Zr	40	41	35	45
Th	-1	1	0	1
U	2	0	1	2
Nb	0	1	0	1
Ba	87	113	101	129
Pb	4	5	7	6
La	6	0	6	-2
Ce	9	9	8	7
Pr	5	-6	7	5
Nd	n.a.	n.a.	n.a.	n.a.

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58941	58942	58943	58944
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #1	N. section #1	N. section #1	N. section #1
Description				
SiO_2	46.88	44.57	51.46	48.37
TiO_2	0.56	0.44	0.84	0.57
Al_2O_3	10.65	7.85	15.13	13.84
Fe_2O_3	11.02	11.77	11.73	11.74
MnO	0.22	0.22	0.18	0.14
MgO	13.84	18.64	5.49	8.86
CaO	12.50	11.78	8.70	11.09
Na_2O	1.48	0.25	2.26	1.88
K_2O	0.29	0.03	1.48	1.40
P_2O_5	0.22	0.15	0.18	0.10
LOI	2.93	4.28	1.85	2.10
Total	100.59	99.98	99.30	100.09
Anhydrous				
SiO_2	48.47	47.07	53.35	49.87
TiO_2	0.58	0.46	0.87	0.59
Al_2O_3	11.01	8.29	15.69	14.27
FeO	8.71	9.51	9.30	9.26
Fe_2O_3	1.71	1.86	1.82	1.82
MnO	0.23	0.23	0.19	0.14
MgO	14.31	19.68	5.69	9.13
CaO	12.92	12.44	9.02	11.43
Na_2O	1.53	0.26	2.34	1.94
K_2O	0.30	0.03	1.53	1.44
P_2O_5	0.23	0.16	0.19	0.10
Normative mineralogy				
q	0.00	0.00	3.37	0.00
or	1.77	0.19	9.06	8.52
ab	12.94	2.23	19.81	16.39
an	22.28	21.33	27.74	25.96
ne	0.00	0.00	0.00	0.00
di_{wo}	16.82	16.40	6.57	12.54
di_{en}	11.15	11.38	3.19	7.23
di_{fs}	4.42	3.64	3.27	4.72
hyen	4.76	14.01	10.93	4.30
hy_{fs}	1.89	4.47	11.22	2.81
fo	13.71	16.39	0.00	7.79
fa	6.00	5.78	0.00	5.62
mt	2.48	2.71	2.65	2.64
il	1.10	0.88	1.66	1.12
ap	0.50	0.35	0.41	0.23
Trace elements (ppm)				
Sc	35	35	26	34
V	291	219	389	315
Cr	445	1058	65	434
Ni	102	374	44	168
Ga	11	9	18	13
Rb	3	2	21	21
Sr	444	167	372	297
Y	17	12	21	16
Zr	42	36	55	36
Th	1	-1	-1	-1
U	2	1	1	0
Nb	1	0	3	1
Ba	75	28	179	144
Pb	5	5	4	5
La	1	-18	13	-6
Ce	8	9	9	11
Pr	13	7	6	3
Nd	n.a.	n.a.	n.a.	n.a.

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58945	58946	58947	58948
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #1	N. section #1	N. section #1	N. section #1
Description				
SiO_2	51.10	49.04	48.83	50.31
TiO_2	1.02	0.72	0.61	0.96
Al_2O_3	16.18	11.33	17.53	15.68
Fe_2O_3	11.43	10.72	9.72	12.84
MnO	0.20	0.20	0.16	0.19
MgO	4.47	10.73	5.22	5.80
CaO	8.28	12.99	10.77	7.61
Na_2O	4.26	1.65	3.71	3.66
K_2O	0.52	0.64	0.99	0.85
P_2O_5	0.20	0.11	0.10	0.21
LOI	2.11	2.23	2.49	1.93
Total	99.77	100.36	100.13	100.04
Anhydrous				
SiO_2	52.85	50.44	50.44	51.86
TiO_2	1.05	0.74	0.63	0.99
Al_2O_3	16.73	11.65	18.11	16.16
FeO	9.04	8.43	7.68	10.12
Fe_2O_3	1.77	1.65	1.51	1.99
MnO	0.21	0.21	0.17	0.20
MgO	4.62	11.04	5.39	5.98
CaO	8.56	13.36	11.12	7.84
Na_2O	4.41	1.70	3.83	3.77
K_2O	0.54	0.66	1.02	0.88
P_2O_5	0.21	0.11	0.10	0.22
Normative mineralogy				
q	0.00	0.00	0.00	0.00
or	3.17	3.89	6.04	5.17
ab	37.25	14.35	25.07	31.89
an	24.29	22.23	29.17	24.57
ne	0.00	0.00	3.97	0.00
di_{wo}	7.02	18.06	10.56	5.38
di_{en}	3.17	11.38	5.39	2.58
di_{fs}	3.81	5.52	4.89	2.73
hyen	4.58	7.70	0.00	6.89
hy_{fs}	5.51	3.74	0.00	7.29
fo	2.60	5.80	5.59	3.75
fa	3.46	3.11	5.59	4.38
mt	2.58	2.40	2.19	2.88
il	2.01	1.41	1.20	1.88
ap	0.45	0.25	0.23	0.47
Trace elements (ppm)				
Sc	25	43	26	31
V	351	284	278	390
Cr	25	419	35	22
Ni	24	96	36	33
Ga	20	12	20	22
Rb	6	11	18	15
Sr	416	192	404	310
Y	26	18	15	25
Zr	79	53	35	71
Th	1	-1	-1	0
U	1	-1	-1	-1
Nb	5	4	0	1
Ba	113	91	77	95
Pb	6	4	5	7
La	16	-2	2	9
Ce	8	8	9	8
Pr	7	0	-2	8
Nd	n.a.	n.a.	n.a.	n.a.

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	**58949**	**58950**	**58951**	**58952**
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #1	N. section #1	N. section #1	N. section #1
Description				
SiO_2	48.10	48.94	55.90	48.03
TiO_2	0.85	0.64	0.75	0.65
Al_2O_3	18.74	13.45	16.91	13.26
Fe_2O_3	11.16	10.74	8.32	10.97
MnO	0.18	0.17	0.18	0.18
MgO	5.14	9.71	3.36	10.28
CaO	8.45	12.20	6.36	12.26
Na_2O	2.99	1.29	4.30	0.92
K_2O	1.82	0.69	1.15	0.70
P_2O_5	0.17	0.13	0.16	0.14
LOI	2.27	2.24	2.09	2.42
Total	99.87	100.20	99.48	99.81
Anhydrous				
SiO_2	49.77	50.43	57.82	49.79
TiO_2	0.88	0.66	0.78	0.67
Al_2O_3	19.39	13.86	17.49	13.75
FeO	8.83	8.46	6.58	8.70
Fe_2O_3	1.73	1.66	1.29	1.71
MnO	0.19	0.18	0.19	0.19
MgO	5.32	10.01	3.48	10.66
CaO	8.74	12.57	6.58	12.71
Na_2O	3.09	1.33	4.45	0.95
K_2O	1.88	0.71	1.19	0.73
P_2O_5	0.18	0.13	0.17	0.15
Normative mineralogy				
q	0.00	0.00	5.57	0.00
or	11.11	4.20	7.02	4.28
ab	26.15	11.24	37.60	8.06
an	33.44	29.74	24.24	31.07
ne	0.00	0.00	0.00	0.00
di_{wo}	3.65	13.23	3.04	12.93
di_{en}	1.76	8.09	1.39	7.99
di_{fs}	1.83	4.37	1.63	4.17
hyen	0.36	14.95	7.23	16.47
hy_{fs}	0.37	8.08	8.46	8.60
fo	7.75	1.24	0.00	1.38
fa	8.88	0.74	0.00	0.80
mt	2.52	2.41	1.88	2.48
il	1.67	1.25	1.48	1.28
ap	0.38	0.29	0.36	0.32
Trace elements (ppm)				
Sc	30	33	17	34
V	358	290	219	286
Cr	25	458	9	477
Ni	24	166	8	168
Ga	18	17	22	13
Rb	30	11	17	14
Sr	431	340	356	335
Y	18	16	27	17
Zr	40	43	67	45
Th	-2	-1	-2	1
U	1	3	1	0
Nb	0	3	4	3
Ba	153	98	178	95
Pb	4	4	4	6
La	7	-9	11	-8
Ce	6	5	8	9
Pr	-1	0	2	3
Nd	n.a.	n.a.	n.a.	n.a.

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58953	58954	58929	58930
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #1	N. section #1	N. section #2	N. section #2
Description				Ol. gabbro
SiO_2	47.59	50.33	45.84	52.92
TiO_2	0.52	0.66	0.38	0.78
Al_2O_3	11.59	13.54	8.11	18.08
Fe_2O_3	11.01	11.02	11.03	8.70
MnO	0.20	0.19	0.18	0.18
MgO	13.51	8.82	19.18	3.81
CaO	11.74	11.50	10.01	8.62
Na_2O	1.01	1.56	0.00	3.00
K_2O	0.64	0.77	0.15	0.24
P_2O_5	0.08	0.14	0.06	0.19
LOI	2.28	1.51	4.65	3.85
Total	100.17	100.04	99.59	100.37
Anhydrous				
SiO_2	49.09	51.57	48.77	55.25
TiO_2	0.54	0.68	0.40	0.81
Al_2O_3	11.95	13.87	8.63	18.88
FeO	8.69	8.64	8.97	6.95
Fe_2O_3	1.70	1.69	1.76	1.36
MnO	0.21	0.19	0.19	0.19
MgO	13.93	9.04	20.40	3.98
CaO	12.11	11.78	10.65	9.00
Na_2O	1.04	1.60	0.00	3.13
K_2O	0.66	0.79	0.16	0.25
P_2O_5	0.08	0.14	0.06	0.20
Normative mineralogy				
q	0.00	0.99	0.00	8.01
or	3.90	4.66	0.94	1.48
ab	8.81	13.51	0.00	26.48
an	25.98	28.34	23.06	36.69
ne	0.00	0.00	0.00	0.00
di_{wo}	13.98	12.16	12.23	2.77
di_{en}	9.22	7.16	8.64	1.31
di_{fs}	3.75	4.38	2.51	1.42
hyen	12.27	15.25	27.62	8.55
hy_{fs}	4.99	9.33	8.03	9.23
fo	9.15	0.00	10.04	0.00
fa	4.10	0.00	3.22	0.00
mt	2.47	2.46	2.56	1.98
il	1.02	1.29	0.77	1.55
ap	0.18	0.31	0.14	0.43
Trace elements (ppm)				
Sc	36	36	28	19
V	279	327	206	226
Cr	636	360	896	6
Ni	206	118	466	11
Ga	13	16	n.a.	n.a.
Rb	11	12	6	6
Sr	177	283	72	401
Y	14	18	8	22
Zr	40	52	25	68
Th	-1	2	0	1
U	1	2	2	0
Nb	0	3	2	4
Ba	88	138	40	28
Pb	4	3	0	4
La	-15	-2	9	1
Ce	6	8	0	11
Pr	-4	-2	n.a.	n.a.
Nd	n.a.	n.a.	2	7

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58931	58931	58932	58933
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description	margin	matrix n=20	core	
SiO_2	48.19	49.18	45.45	48.28
TiO_2	0.63	0.50	0.49	0.65
Al_2O_3	13.19	15.55	10.26	13.76
Fe_2O_3	11.96	11.00	11.60	11.18
MnO	0.17	0.16	0.18	0.17
MgO	10.26	8.68	17.43	9.02
CaO	10.17	7.53	10.15	11.56
Na_2O	2.37	4.16	0.00	1.82
K_2O	0.82	0.96	0.30	1.39
P_2O_5	0.12	b.d.l.	0.09	0.19
LOI	2.97	n.a.	5.34	2.21
Total	100.85	97.72	101.29	100.23
Anhydrous				
SiO_2	49.75	50.81	47.86	49.74
TiO_2	0.65	0.52	0.52	0.67
Al_2O_3	13.62	16.07	10.80	14.18
FeO	9.44	8.69	9.34	8.81
Fe_2O_3	1.85	1.70	1.83	1.73
MnO	0.18	0.17	0.19	0.18
MgO	10.59	8.97	18.35	9.29
CaO	10.50	7.78	10.69	11.91
Na_2O	2.45	4.30	0.00	1.87
K_2O	0.85	0.99	0.32	1.43
P_2O_5	0.12	b.d.l.	0.09	0.20
Normative mineralogy				
q	0.00	0.00	0.00	0.00
or	5.00	5.85	1.86	8.45
ab	20.68	30.46	0.00	15.85
an	23.66	21.61	28.53	26.02
ne	0.00	3.19	0.00	0.00
di_{wo}	11.51	7.08	9.95	13.24
di_{en}	6.91	4.13	6.85	7.82
di_{fs}	3.97	2.60	2.28	4.74
hy_{en}	4.14	0.00	25.16	3.89
hy_{fs}	2.38	0.00	8.37	2.36
fo	10.65	12.68	9.46	7.93
fa	6.75	8.82	3.48	5.31
mt	2.69	2.48	2.66	2.51
il	1.24	0.98	0.98	1.27
ap	0.27	0.00	0.21	0.43
Trace elements (ppm)				
Sc	31		24	34
V	317		233	307
Cr	330		703	331
Ni	144		472	121
Ga	n.a.		n.a.	n.a.
Rb	14		8	21
Sr	253		130	390
Y	13		11	16
Zr	43		36	51
Th	2		0	0
U	3		0	2
Nb	1		1	1
Ba	75		32	143
Pb	5		7	0
La	3		0	11
Ce	5		1	17
Pr	n.a.		n.a.	n.a.
Nd	6		1	2

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58933	58934	58935	58935
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description	matrix n=20		stock	matrix n=15
SiO_2	52.39	48.44	53.11	55.71
TiO_2	0.63	0.76	0.86	0.73
Al_2O_3	16.71	16.41	16.59	16.58
Fe_2O_3	9.25	10.44	9.83	6.81
MnO	0.34	0.15	0.19	0.32
MgO	6.67	7.69	4.19	2.30
CaO	10.23	10.54	5.88	5.62
Na_2O	1.46	1.60	6.67	6.90
K_2O	1.80	1.60	0.48	0.41
P_2O_5	b.d.l.	0.21	0.36	b.d.l.
LOI	b.d.l.	3.65	2.42	b.d.l.
Total	99.48	101.49	100.58	95.37
Anhydrous				
SiO_2	53.09	49.96	54.57	58.77
TiO_2	0.64	0.78	0.88	0.77
Al_2O_3	16.93	16.93	17.05	17.49
FeO	7.17	8.24	7.73	5.49
Fe_2O_3	1.41	1.62	1.52	1.08
MnO	0.34	0.15	0.20	0.33
MgO	6.76	7.93	4.31	2.42
CaO	10.37	10.87	6.04	5.93
Na_2O	1.48	1.65	6.85	7.28
K_2O	1.82	1.65	0.49	0.43
P_2O_5	b.d.l.	0.22	0.37	b.d.l.
Normative mineralogy				
q		0.00	0.00	
or		9.74	2.91	
ab		13.95	50.18	
an		33.89	14.29	
ne		0.00	4.20	
di_{wo}		7.76	5.53	
di_{en}		4.48	2.59	
di_{fs}		2.91	2.87	
hy_{en}		10.14	0.00	
hy_{fs}		6.59	0.00	
fo		3.53	5.66	
fa		2.54	6.93	
mt		2.35	2.20	
il		1.49	1.68	
ap		0.47	0.81	
Trace elements (ppm)				
Sc		27	20	
V		335	214	
Cr		191	54	
Ni		104	20	
Ga		n.a.	n.a.	
Rb		23	7	
Sr		511	413	
Y		17	29	
Zr		48	97	
Th		0	2	
U		2	3	
Nb		3	2	
Ba		96	63	
Pb		8	5	
La		10	7	
Ce		11	17	
Pr		n.a.	n.a.	
Nd		1	21	

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58936	58955	58955	58956
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description		margin	matrix n=20	core
SiO_2	47.40	50.12	50.16	48.81
TiO_2	0.60	0.90	1.06	0.61
Al_2O_3	11.96	18.17	15.65	12.20
Fe_2O_3	11.83	11.07	13.43	10.75
MnO	0.20	0.18	0.36	0.18
MgO	12.23	3.77	5.07	10.12
CaO	11.15	8.86	9.10	12.53
Na_2O	1.61	4.27	4.06	1.08
K_2O	0.52	1.42	0.74	0.54
P_2O_5	0.13	0.21	0.39	0.13
LOI	3.66	2.41	n.a.	2.46
Total	101.29	101.38	100.02	99.41
Anhydrous				
SiO_2	49.06	51.13	50.73	50.83
TiO_2	0.62	0.92	1.07	0.64
Al_2O_3	12.38	18.54	15.83	12.70
FeO	9.36	8.64	10.39	8.56
Fe_2O_3	1.84	1.69	2.04	1.68
MnO	0.21	0.18	0.36	0.19
MgO	12.66	3.85	5.13	10.54
CaO	11.54	9.04	9.20	13.05
Na_2O	1.67	4.36	4.11	1.12
K_2O	0.54	1.45	0.75	0.56
P_2O_5	0.13	0.21	0.39	0.14
Normative mineralogy				
q	0.00	0.00	0.00	0.39
or	3.18	8.55	4.42	3.32
ab	14.09	31.14	34.71	9.51
an	24.69	26.74	22.54	27.94
ne	0.00	3.08	0.00	0.00
di_{wo}	13.20	6.96	8.56	14.96
di_{en}	8.35	2.92	3.74	9.24
di_{fs}	4.00	4.07	4.80	4.82
hyen	8.59	0.00	0.09	16.89
hy_{fs}	4.12	0.00	0.12	8.82
fo	10.12	4.63	6.22	0.00
fa	5.35	7.13	8.80	0.00
mt	2.67	2.46	2.96	2.44
il	1.18	1.75	2.04	1.21
ap	0.29	0.47	0.86	0.30
Trace elements (ppm)				
Sc	28	23		34
V	288	389		281
Cr	524	20		459
Ni	249	22		135
Ga	n.a.	n.a.		n.a.
Rb	7	19		10
Sr	292	557		323
Y	14	21		16
Zr	40	62		44
Th	0	0		0
U	0	2		0
Nb	1	4		3
Ba	59	164		81
Pb	3	5		2
La	5	8		9
Ce	6	13		4
Pr	n.a.	n.a.		n.a.
Nd	2	9		3

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58956	58957	58957	58958
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description	matrix n=18		matrix n=20	margin
SiO_2	50.75	47.66	51.74	51.34
TiO_2	0.65	0.78	0.68	0.81
Al_2O_3	14.51	14.03	15.37	18.63
Fe_2O_3	11.90	12.21	11.71	10.37
MnO	b.d.l.	0.20	0.31	0.12
MgO	8.71	8.84	7.46	3.43
CaO	11.26	10.51	9.01	7.94
Na_2O	1.93	1.65	2.39	3.86
K_2O	0.16	1.26	1.00	2.18
P_2O_5	0.14	0.17	0.24	0.16
LOI	b.d.l.	3.47	b.d.l.	3.99
Total	100.01	100.78	99.91	102.83
Anhydrous				
SiO_2	51.26	49.51	52.31	52.41
TiO_2	0.66	0.81	0.69	0.83
Al_2O_3	14.66	14.57	15.54	19.02
FeO	9.19	9.70	9.05	8.10
Fe_2O_3	1.80	1.90	1.78	1.59
MnO	0.00	0.21	0.31	0.12
MgO	8.80	9.18	7.54	3.50
CaO	11.37	10.92	9.11	8.11
Na_2O	1.95	1.71	2.42	3.94
K_2O	0.16	1.31	1.01	2.23
P_2O_5	0.14	0.18	0.24	0.16
Normative mineralogy				
q	1.04	0.00	0.90	0.00
or	0.95	7.73	5.97	13.14
ab	16.48	14.49	20.43	33.02
an	30.75	28.19	28.56	27.62
ne	0.00	0.00	0.00	0.16
di_{wo}	10.31	10.34	6.27	4.80
di_{en}	5.94	5.91	3.39	1.98
di_{fs}	3.90	3.97	2.65	2.84
hyen	15.88	8.79	15.31	0.00
hy_{fs}	10.42	5.90	11.96	0.00
fo	0.00	5.66	0.00	4.69
fa	0.00	4.19	0.00	7.41
mt	2.62	2.76	2.58	2.31
il	1.25	1.54	1.31	1.57
ap	0.31	0.39	0.53	0.36
Trace elements (ppm)				
Sc		33		19
V		363		349
Cr		354		9
Ni		119		17
Ga		n.a.		n.a.
Rb		15		33
Sr		348		505
Y		18		20
Zr		54		54
Th		0		0
U		2		0
Nb		2		1
Ba		124		186
Pb		3		2
La		9		12
Ce		0		12
Pr		n.a.		n.a.
Nd		5		5

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58958	58959	58960	58961
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description	matrix n=17	core		
SiO_2	51.62	50.81	52.49	47.97
TiO_2	1.08	0.74	0.85	0.83
Al_2O_3	17.48	17.06	16.24	18.25
Fe_2O_3	12.43	10.44	10.55	11.57
MnO	0.19	0.17	0.16	0.18
MgO	4.11	4.93	4.75	5.87
CaO	8.43	9.69	8.25	7.65
Na_2O	4.44	3.31	2.89	3.25
K_2O	1.28	1.34	1.77	1.55
P_2O_5	b.d.l.	0.15	0.18	0.16
LOI	n.a.	2.18	2.38	3.48
Total	101.06	100.82	100.51	100.76
Anhydrous				
SiO_2	51.62	51.98	53.98	49.82
TiO_2	1.08	0.76	0.87	0.86
Al_2O_3	17.48	17.45	16.70	18.95
FeO	9.51	8.17	8.30	9.19
Fe_2O_3	1.86	1.60	1.63	1.80
MnO	0.19	0.17	0.16	0.19
MgO	4.11	5.04	4.89	6.10
CaO	8.43	9.91	8.48	7.94
Na_2O	4.44	3.39	2.97	3.38
K_2O	1.28	1.37	1.82	1.61
P_2O_5	b.d.l.	0.15	0.19	0.17
Normative mineralogy				
q	0.00	0.00	2.00	0.00
or	7.55	8.09	10.74	9.50
ab	34.03	28.63	25.13	28.53
an	23.98	28.36	26.85	31.80
ne	1.90	0.00	0.00	0.00
di_{wo}	7.43	8.25	5.85	2.71
di_{en}	3.08	4.01	2.80	1.36
di_{fs}	4.39	4.09	2.95	1.29
hyen	0.00	3.19	9.31	0.71
hy_{fs}	0.00	3.26	9.81	0.68
fo	4.98	3.71	0.00	9.13
fa	7.81	4.18	0.00	9.54
mt	2.71	2.33	2.36	2.62
il	2.05	1.44	1.66	1.64
ap	0.00	0.34	0.40	0.36
Trace elements (ppm)				
Sc		25	24	29
V		308	355	240
Cr		91	34	30
Ni		39	30	34
Ga		n.a.	n.a.	n.a.
Rb		16	24	25
Sr		377	422	500
Y		17	19	37
Zr		50	62	34
Th		0	0	0
U		4	0	1
Nb		1	2	1
Ba		160	177	102
Pb		3	3	5
La		10	12	12
Ce		9	13	12
Pr		n.a.	n.a.	n.a.
Nd		4	5	7

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58962	58963	58964	58964
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description	breccia	host dike	core dike	matrix n=20
SiO_2	47.12	49.73	49.27	53.04
TiO_2	0.79	0.81	0.74	0.78
Al_2O_3	18.44	16.67	16.98	16.68
Fe_2O_3	11.33	12.20	11.34	11.70
MnO	0.13	0.20	0.23	0.29
MgO	6.36	4.90	5.36	4.50
CaO	10.10	10.29	11.06	10.09
Na_2O	2.85	2.01	1.77	1.84
K_2O	1.04	1.30	1.33	0.96
P_2O_5	0.13	0.19	0.15	b.d.l.
LOI	4.65	0.93	1.43	n.a.
Total	102.94	99.23	99.66	99.89
Anhydrous				
SiO_2	48.42	51.13	50.66	53.64
TiO_2	0.81	0.83	0.76	0.79
Al_2O_3	18.95	17.14	17.46	16.87
FeO	8.90	9.59	8.92	9.05
Fe_2O_3	1.75	1.88	1.75	1.77
MnO	0.13	0.21	0.24	0.29
MgO	6.53	5.04	5.51	4.55
CaO	10.38	10.58	11.37	10.21
Na_2O	2.93	2.07	1.82	1.86
K_2O	1.07	1.34	1.37	0.97
P_2O_5	0.13	0.20	0.15	n.a.
Normative mineralogy				
q	0.00	1.31	0.58	
or	6.31	7.89	8.07	
ab	22.70	17.47	15.38	
an	35.38	33.53	35.41	
ne	1.12	0.00	0.00	
di_{wo}	6.34	7.36	8.33	
di_{en}	3.32	3.32	4.03	
di_{fs}	2.83	4.00	4.16	
hyen	0.00	9.18	9.64	
hy_{fs}	0.00	11.08	9.96	
fo	9.02	0.00	0.00	
fa	8.49	0.00	0.00	
mt	2.54	2.73	2.54	
il	1.54	1.58	1.45	
ap	0.29	0.43	0.34	
Trace elements (ppm)				
Sc	29	26	27	
V	327	357	367	
Cr	59	25	61	
Ni	40	30	40	
Ga	n.a.	n.a.	n.a.	
Rb	18	19	18	
Sr	747	403	369	
Y	16	18	16	
Zr	40	52	47	
Th	0	1	2	
U	2	3	2	
Nb	1	0	2	
Ba	95	138	169	
Pb	5	2	2	
La	14	9	8	
Ce	9	9	12	
Pr	n.a.	n.a.	n.a.	
Nd	4	13	14	

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58965	58966	58966	58967
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description		margin	matrix n=20	core
SiO_2	49.42	48.53	47.93	48.02
TiO_2	0.90	0.87	0.85	0.64
Al_2O_3	16.06	15.60	14.98	11.12
Fe_2O_3	10.88	11.43	10.26	10.78
MnO	0.19	0.18	0.25	0.16
MgO	6.08	7.23	4.41	12.04
CaO	10.30	9.65	8.56	13.01
Na_2O	2.75	3.10	2.86	0.94
K_2O	1.22	1.12	1.04	0.54
P_2O_5	0.19	0.19	b.d.l.	0.12
LOI	1.83	2.19	n.a.	2.46
Total	99.82	100.09	91.13	99.83
Anhydrous				
SiO_2	50.92	50.07	53.11	49.79
TiO_2	0.93	0.90	0.94	0.66
Al_2O_3	16.55	16.09	16.60	11.53
FeO	8.57	9.02	8.69	8.55
Fe_2O_3	1.68	1.77	1.71	1.68
MnO	0.20	0.19	0.28	0.17
MgO	6.26	7.46	4.88	12.48
CaO	10.61	9.96	9.48	13.49
Na_2O	2.83	3.20	3.17	0.97
K_2O	1.26	1.16	1.15	0.56
P_2O_5	0.20	0.20	b.d.l.	0.12
Normative mineralogy				
q	0.00	0.00		0.00
or	7.42	6.82		3.30
ab	23.95	26.80		8.24
an	28.71	26.14		25.42
ne	0.00	0.13		0.00
di_{wo}	9.44	9.15		16.96
di_{en}	4.95	5.02		10.98
di_{fs}	4.20	3.79		4.80
hyen	4.48	0.00		13.58
hy_{fs}	3.80	0.00		5.93
fo	4.28	9.44		4.48
fa	4.01	7.87		2.16
mt	2.44	2.57		2.44
il	1.76	1.71		1.26
ap	0.43	0.43		0.27
Trace elements (ppm)				
Sc	25	31		40
V	339	340		269
Cr	126	120		565
Ni	54	68		185
Ga	n.a.	n.a.		n.a.
Rb	19	18		8
Sr	377	435		246
Y	20	20		14
Zr	61	65		47
Th	0	0		2
U	3	0		0
Nb	3	1		0
Ba	133	134		80
Pb	0	2		0
La	10	15		13
Ce	14	16		2
Pr	n.a.	n.a.		n.a.
Nd	11	12		8

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58968	58968	58969	58970
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description	margin	matrix n=17	core	
SiO_2	50.04	52.75	47.13	51.35
TiO_2	0.68	0.49	0.52	1.10
Al_2O_3	15.21	16.46	11.44	18.17
Fe_2O_3	11.91	11.31	11.37	10.25
MnO	0.21	0.01	0.18	0.18
MgO	6.29	5.69	12.75	3.43
CaO	9.80	9.61	11.70	7.24
Na_2O	3.15	3.83	0.98	3.63
K_2O	1.16	0.81	0.64	1.58
P_2O_5	0.14	b.d.l.	0.10	0.18
LOI	1.95	n.a.	3.91	2.47
Total	100.54	100.96	100.72	99.58
Anhydrous				
SiO_2	51.28	52.75	49.17	53.36
TiO_2	0.70	0.49	0.54	1.14
Al_2O_3	15.59	16.46	11.94	18.88
FeO	9.34	8.65	9.07	8.15
Fe_2O_3	1.83	1.70	1.78	1.60
MnO	0.22	0.01	0.19	0.19
MgO	6.45	5.69	13.30	3.56
CaO	10.04	9.61	12.21	7.52
Na_2O	3.23	3.83	1.02	3.77
K_2O	1.19	0.81	0.67	1.64
P_2O_5	0.14	b.d.l.	0.10	0.19
Normative mineralogy				
q	0.00	0.00	0.00	0.09
or	7.02	4.78	3.94	9.69
ab	27.29	32.38	8.64	31.89
an	24.52	25.32	25.99	29.73
ne	0.00	0.00	0.00	0.00
di_{wo}	10.15	9.31	14.12	2.65
di_{en}	5.13	4.63	9.11	1.12
di_{fs}	4.78	4.49	4.04	1.53
hyen	2.49	3.51	12.98	7.72
hy_{fs}	2.32	3.41	5.77	10.57
fo	5.86	4.18	7.63	0.00
fa	6.02	4.48	3.74	0.00
mt	2.66	2.46	2.59	2.32
il	1.33	0.93	1.03	2.17
ap	0.31	0.00	0.23	0.41
Trace elements (ppm)				
Sc	32		33	24
V	360		273	332
Cr	77		545	12
Ni	48		217	13
Ga	n.a.		n.a.	n.a.
Rb	19		13	26
Sr	409		210	377
Y	16		11	25
Zr	42		35	69
Th	0		0	0
U	1		0	0
Nb	0		2	2
Ba	146		82	158
Pb	34		8	6
La	7		7	8
Ce	12		4	11
Pr	n.a.		n.a.	n.a.
Nd	0		0	2

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58971	58972	58973	58974
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description				core
SiO_2	48.92	51.74	48.44	47.49
TiO_2	0.75	0.87	0.65	0.76
Al_2O_3	13.80	16.13	14.69	13.67
Fe_2O_3	10.93	10.84	11.39	12.08
MnO	0.18	0.18	0.15	0.18
MgO	9.06	4.18	9.10	9.24
CaO	11.95	6.43	10.57	9.91
Na_2O	1.50	3.29	1.61	2.33
K_2O	1.04	2.69	1.41	1.26
P_2O_5	0.16	0.18	0.12	0.15
LOI	2.60	2.78	2.47	3.26
Total	100.89	99.31	100.60	100.33
Anhydrous				
SiO_2	50.25	54.12	49.86	49.45
TiO_2	0.77	0.91	0.67	0.79
Al_2O_3	14.17	16.87	15.12	14.23
FeO	8.59	8.67	8.97	9.62
Fe_2O_3	1.68	1.70	1.76	1.89
MnO	0.18	0.19	0.15	0.19
MgO	9.31	4.37	9.37	9.62
CaO	12.27	6.73	10.88	10.32
Na_2O	1.54	3.44	1.66	2.43
K_2O	1.07	2.81	1.45	1.31
P_2O_5	0.16	0.19	0.12	0.16
Normative mineralogy				
q	0.00	0.00	0.00	0.00
or	6.30	16.61	8.57	7.74
ab	13.02	29.09	14.01	20.51
an	28.59	22.27	29.52	24.06
ne	0.00	0.00	0.00	0.00
di_{wo}	13.01	4.11	9.85	10.88
di_{en}	7.78	1.83	5.80	6.33
di_{fs}	4.54	2.26	3.55	4.02
hy_{en}	10.92	7.25	9.18	1.89
hy_{fs}	6.37	8.94	5.61	1.20
fo	3.07	1.24	5.77	10.95
fa	1.97	1.68	3.89	7.68
mt	2.45	2.47	2.55	2.74
il	1.47	1.73	1.27	1.51
ap	0.36	0.41	0.27	0.34
Trace elements (ppm)				
Sc	32	32	31	32
V	306	347	299	363
Cr	356	36	289	394
Ni	137	31	150	135
Ga	n.a.	n.a.	n.a.	n.a.
Rb	16	39	24	20
Sr	380	341	286	257
Y	17	21	15	17
Zr	49	59	42	51
Th	3	3	2	0
U	1	0	3	2
Nb	0	0	1	0
Ba	112	224	149	135
Pb	7	7	5	4
La	11	9	9	12
Ce	8	13	9	3
Pr	n.a.	n.a.	n.a.	n.a.
Nd	11	10	7	6

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58975	58976	58977	58977
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	N. section #2	N. section #2	N. section #2
Description	margin		Cse. Xtal lithic tuff	Fine Xtal lithic tuff
SiO_2	49.74	50.02	47.20	48.34
TiO_2	0.68	0.85	0.70	0.86
Al_2O_3	14.39	15.39	16.73	19.20
Fe_2O_3	10.45	12.51	10.48	10.51
MnO	0.17	0.20	0.22	0.20
MgO	7.83	4.68	8.41	6.76
CaO	10.88	7.94	10.13	7.03
Na_2O	2.20	4.20	2.49	3.58
K_2O	1.51	0.84	0.83	0.82
P_2O_5	0.16	0.18	0.12	0.12
LOI	1.91	2.65	6.33	5.59
Total	99.92	99.46	103.64	103.01
Anhydrous				
SiO_2	51.21	52.24	48.95	50.08
TiO_2	0.70	0.89	0.73	0.89
Al_2O_3	14.82	16.07	17.35	19.89
FeO	8.23	9.99	8.32	8.33
Fe_2O_3	1.61	1.96	1.63	1.64
MnO	0.18	0.21	0.23	0.21
MgO	8.06	4.89	8.72	7.00
CaO	11.20	8.29	10.51	7.28
Na_2O	2.27	4.39	2.58	3.71
K_2O	1.55	0.88	0.86	0.85
P_2O_5	0.16	0.19	0.12	0.12
Normative mineralogy				
q	0.00	0.00	0.00	0.00
or	9.18	5.18	5.08	5.02
ab	19.15	37.08	21.81	31.36
an	25.66	21.57	33.21	35.09
ne	0.00	0.00	0.00	0.00
di_{wo}	12.02	7.64	7.56	0.09
di_{en}	6.95	3.33	4.46	0.05
di_{fs}	4.50	4.30	2.71	0.04
hy_{en}	6.03	1.51	2.12	3.97
hy_{fs}	3.91	1.95	1.29	2.94
fo	4.91	5.10	10.53	9.34
fa	3.51	7.27	7.07	7.64
mt	2.34	2.85	2.37	2.38
il	1.33	1.69	1.39	1.69
ap	0.36	0.41	0.26	0.26
Trace elements (ppm)				
Sc	31	35	36	24
V	460	290	303	301
Cr	15	267	159	25
Ni	25	73	n.a.	n.a.
Ga	n.a.	n.a.	22	16
Rb	12	20	14	15
Sr	423	339	542	545
Y	18	16	16	20
Zr	47	49	32	37
Th	0	2	-1	1
U	3	3	1	0
Nb	3	2	n.a.	n.a.
Ba	144	140	81	70
Pb	3	4	6	6
La	14	7	-1	3
Ce	14	12	8	6
Pr	n.a.	n.a.	3	3
Nd	11	6	n.a.	n.a.

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58978	58981	58982	58983
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	N. section #2	S. section	S. section	S. section
Description	Tuff breccia			
SiO_2	46.59	51.01	50.02	50.97
TiO_2	0.83	0.69	0.80	0.77
Al_2O_3	19.16	12.86	16.98	17.17
Fe_2O_3	11.15	12.09	11.09	10.62
MnO	0.19	0.25	0.25	0.21
MgO	5.57	7.52	5.19	4.60
CaO	10.01	7.51	7.77	7.98
Na_2O	3.40	2.52	2.49	3.25
K_2O	0.55	0.26	2.42	1.28
P_2O_5	0.11	0.13	0.16	0.16
LOI	5.95	4.61	3.08	2.53
Total	103.51	99.45	100.25	99.54
Anhydrous				
SiO_2	48.22	54.38	51.98	53.04
TiO_2	0.86	0.74	0.83	0.80
Al_2O_3	19.83	13.71	17.65	17.87
FeO	8.83	9.86	8.81	8.45
Fe_2O_3	1.73	1.93	1.73	1.66
MnO	0.20	0.27	0.26	0.22
MgO	5.77	8.02	5.39	4.79
CaO	10.36	8.01	8.07	8.30
Na_2O	3.52	2.69	2.59	3.38
K_2O	0.57	0.28	2.51	1.33
P_2O_5	0.11	0.14	0.17	0.17
Normative mineralogy				
q	0.00	4.87	0.00	0.04
or	3.36	1.64	14.84	7.86
ab	24.88	22.71	21.88	28.59
an	36.61	24.52	29.09	29.62
ne	2.65	0.00	0.00	0.00
di_{wo}	5.85	5.95	4.11	4.36
di_{en}	2.92	3.20	1.98	2.04
di_{fs}	2.81	2.54	2.06	2.27
hyen	0.00	16.68	8.12	9.83
hy_{fs}	0.00	13.25	8.42	10.97
fo	7.97	0.00	2.29	0.00
fa	8.45	0.00	2.62	0.00
mt	2.51	2.81	2.51	2.41
il	1.64	1.40	1.58	1.52
ap	0.24	0.30	0.36	0.36
Trace elements (ppm)				
Sc	30	31	28	26
V	313	354	357	386
Cr	50	178	50	31
Ni	n.a.	71	32	27
Ga	20	14	19	15
Rb	14	6	57	32
Sr	931	230	348	452
Y	19	18	20	21
Zr	25	44	51	52
Th	0	1	1	3
U	2	-1	2	3
Nb	n.a.	1	2	2
Ba	50	61	317	143
Pb	6	3	7	7
La	3	-5	7	5
Ce	8	7	7	8
Pr	-1	-1	6	2
Nd	n.a.	n.a.	n.a.	n.a.

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58984	58985	58986	58987
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	S. section	S. section	S. section	S. section
Description				
SiO_2	48.50	51.58	48.31	45.91
TiO_2	0.64	1.12	0.86	0.77
Al_2O_3	15.50	16.70	14.77	12.00
Fe_2O_3	9.46	10.40	11.27	11.16
MnO	0.13	0.15	0.20	0.21
MgO	4.19	5.87	8.51	11.25
CaO	17.04	6.43	10.72	14.26
Na_2O	b.d.l.	3.04	1.71	0.96
K_2O	0.01	1.79	1.30	0.13
P_2O_5	0.13	0.20	0.15	0.13
LOI	4.27	2.76	2.51	3.37
Total	99.87	100.04	100.31	100.15
Anhydrous				
SiO_2	51.16	53.51	49.89	47.91
TiO_2	0.68	1.16	0.89	0.80
Al_2O_3	16.35	17.32	15.25	12.52
FeO	7.63	8.25	8.90	8.91
Fe_2O_3	1.50	1.62	1.75	1.75
MnO	0.14	0.16	0.21	0.22
MgO	4.42	6.09	8.79	11.74
CaO	17.98	6.67	11.07	14.88
Na_2O	0.00	3.15	1.77	1.00
K_2O	0.01	1.86	1.34	0.14
P_2O_5	0.14	0.21	0.15	0.14
Normative mineralogy				
q	10.41	0.61	0.00	0.00
or	0.06	10.96	7.92	0.80
ab	0.00	26.66	14.93	8.47
an	44.56	27.62	29.71	29.26
ne	0.00	0.00	0.00	0.00
di_{wo}	18.22	1.71	10.08	18.20
di_{en}	8.61	0.91	5.87	11.50
di_{fs}	9.36	0.74	3.72	5.53
hyen	2.35	14.19	9.23	6.92
hy_{fs}	2.56	11.45	5.86	3.33
fo	0.00	0.00	4.69	7.49
fa	0.00	0.00	3.28	3.97
mt	2.17	2.35	2.54	2.54
il	1.28	2.21	1.69	1.53
ap	0.30	0.45	0.34	0.30
Trace elements (ppm)				
Sc	28	24	34	42
V	332	341	308	303
Cr	94	34	211	574
Ni	42	31	104	191
Ga	21	20	17	17
Rb	3	48	22	4
Sr	26	386	235	449
Y	18	27	24	20
Zr	52	87	71	55
Th	0	-1	1	-1
U	1	3	1	1
Nb	2	1	4	3
Ba	27	264	203	53
Pb	10	6	2	4
La	3	12	1	-8
Ce	7	9	8	9
Pr	2	8	6	3
Nd	n.a.	n.a.	n.a.	n.a.

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58988	58989	58990	58991
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	S. section	S. section	S. section	S. section
Description				
SiO_2	51.89	49.00	51.09	48.72
TiO_2	0.79	0.82	0.79	0.68
Al_2O_3	16.70	17.79	15.76	14.67
Fe_2O_3	9.71	10.44	10.37	10.08
MnO	0.18	0.18	0.17	0.27
MgO	5.76	5.81	6.08	7.01
CaO	7.12	8.86	8.26	11.04
Na_2O	2.41	1.86	2.10	1.78
K_2O	1.48	2.28	1.19	0.80
P_2O_5	0.17	0.17	0.16	0.14
LOI	3.57	3.37	4.32	5.54
Total	99.78	100.58	100.29	100.73
Anhydrous				
SiO_2	54.40	50.87	53.73	51.65
TiO_2	0.83	0.85	0.83	0.72
Al_2O_3	17.51	18.47	16.57	15.55
FeO	7.79	8.29	8.34	8.17
Fe_2O_3	1.53	1.63	1.64	1.60
MnO	0.19	0.19	0.18	0.29
MgO	6.04	6.03	6.39	7.43
CaO	7.46	9.20	8.69	11.70
Na_2O	2.53	1.93	2.21	1.89
K_2O	1.55	2.37	1.25	0.85
P_2O_5	0.18	0.18	0.17	0.15
Normative mineralogy				
q	4.66	0.00	4.78	1.29
or	9.16	13.97	7.39	5.01
ab	21.36	16.32	18.67	15.95
an	31.84	34.72	31.60	31.44
ne	0.00	0.00	0.00	0.00
di_{wo}	1.67	4.06	4.32	10.68
di_{en}	0.90	2.12	2.30	6.00
di_{fs}	0.72	1.82	1.88	4.24
hy_{en}	14.08	10.09	13.55	12.43
hy_{fs}	11.31	8.65	11.05	8.79
fo	0.00	1.92	0.00	0.00
fa	0.00	1.82	0.00	0.00
mt	2.22	2.36	2.38	2.33
il	1.58	1.62	1.58	1.37
ap	0.39	0.39	0.37	0.32
Trace elements (ppm)				
Sc	23	28	29	28
V	329	343	327	321
Cr	87	143	130	256
Ni	41	65	52	80
Ga	20	19	17	21
Rb	37	44	19	12
Sr	299	444	317	448
Y	21	21	22	20
Zr	56	56	61	51
Th	1	1	2	0
U	1	1	2	0
Nb	2	1	1	2
Ba	148	321	206	149
Pb	8	5	4	6
La	8	3	12	0
Ce	9	8	9	9
Pr	3	5	2	2
Nd	n.a.	n.a.	n.a.	n.a.

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58992	58993	58994	58995
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.
Member/Section	S. section	S. section	S. section	S. section
Description				
SiO_2	52.61	48.87	50.18	49.27
TiO_2	0.85	0.61	0.71	0.71
Al_2O_3	15.36	10.82	17.02	18.23
Fe_2O_3	10.38	10.28	10.03	9.10
MnO	0.17	0.20	0.20	0.19
MgO	8.31	11.52	5.24	2.75
CaO	4.18	12.73	9.83	8.92
Na_2O	1.77	1.65	2.22	4.02
K_2O	1.78	0.27	2.29	1.47
P_2O_5	0.17	0.12	0.14	0.19
LOI	4.57	4.03	2.57	5.06
Total	100.15	101.10	100.43	99.91
Anhydrous				
SiO_2	55.56	50.80	51.73	52.37
TiO_2	0.90	0.63	0.73	0.75
Al_2O_3	16.22	11.25	17.55	19.38
FeO	8.38	8.17	7.91	7.40
Fe_2O_3	1.64	1.60	1.55	1.45
MnO	0.18	0.21	0.21	0.20
MgO	8.78	11.98	5.40	2.92
CaO	4.41	13.23	10.13	9.48
Na_2O	1.87	1.72	2.29	4.27
K_2O	1.88	0.28	2.36	1.56
P_2O_5	0.18	0.12	0.14	0.20
Normative mineralogy				
q	7.52	0.00	0.00	0.00
or	11.09	1.66	13.93	9.22
ab	15.80	14.50	19.35	33.47
an	30.30	22.15	30.62	29.07
ne	0.00	0.00	0.00	1.44
di_{wo}	-4.00	17.79	7.79	6.93
di_{en}	-2.38	11.51	3.95	2.71
di_{fs}	0.00	5.05	3.66	4.31
hyen	24.15	11.15	6.33	0.00
hy_{fs}	14.31	4.89	5.87	0.00
fo	0.00	4.93	2.18	3.18
fa	0.00	2.39	2.23	5.57
mt	2.39	2.33	2.25	2.11
il	1.71	1.21	1.39	1.44
ap	0.39	0.27	0.32	0.44
Trace elements (ppm)				
Sc	26	34	27	19
V	286	270	301	277
Cr	15	455	116	9
Ni	18	166	55	14
Ga	13	14	19	21
Rb	27	4	41	31
Sr	239	180	375	427
Y	21	16	18	19
Zr	65	47	47	59
Th	0	-1	1	2
U	3	1	1	1
Nb	1	1	9	3
Ba	383	60	288	248
Pb	5	7	7	6
La	5	-15	4	14
Ce	8	9	8	8
Pr	4	2	3	9
Nd	n.a.	n.a.	n.a.	n.a.

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58925	58980	58996	58926
Unit	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Mantle Volcanics Fm.	Skippers Fm.
Member/Section				Hokuri Amphibolites
Description	Tuff breccia		Tuff breccia	Mega-xstic amphibolite
SiO_2	49.27	50.31	47.86	46.70
TiO_2	0.72	0.80	0.69	0.73
Al_2O_3	16.19	18.10	12.12	9.77
Fe_2O_3	11.15	10.52	10.60	14.43
MnO	0.19	0.21	0.19	0.27
MgO	6.47	4.60	12.14	12.64
CaO	10.31	6.51	10.85	12.24
Na_2O	3.04	4.41	1.02	0.53
K_2O	0.84	0.84	0.83	0.16
P_2O_5	0.15	0.17	0.09	0.04
LOI	5.86	2.92	7.32	5.56
Total	104.19	99.39	103.71	103.07
Anhydrous				
SiO_2	50.60	52.64	50.12	48.50
TiO_2	0.74	0.84	0.72	0.76
Al_2O_3	16.63	18.94	12.69	10.15
FeO	8.76	8.42	8.49	11.47
Fe_2O_3	1.71	1.65	1.67	2.24
MnO	0.20	0.22	0.20	0.28
MgO	6.64	4.81	12.71	13.13
CaO	10.59	6.81	11.36	12.71
Na_2O	3.12	4.61	1.07	0.55
K_2O	0.86	0.88	0.87	0.17
P_2O_5	0.15	0.18	0.09	0.04
Normative mineralogy				
q	0.00	0.00	0.00	0.00
or	5.08	5.19	5.14	1.00
ab	26.38	39.01	9.05	4.65
an	28.82	28.36	27.24	24.71
ne	0.00	0.00	0.00	0.00
di_{wo}	9.47	1.77	11.89	15.87
di_{en}	4.99	0.83	7.75	9.57
di_{fs}	4.19	0.92	3.29	5.43
hyen	2.54	4.04	17.71	17.79
hy_{fs}	2.13	4.44	7.53	10.10
fo	6.26	4.94	4.25	3.64
fa	5.80	6.00	1.99	2.28
mt	2.48	2.40	2.43	3.25
il	1.41	1.59	1.37	1.45
ap	0.33	0.39	0.20	0.09
Trace elements (ppm)				
Sc	37	25	35	58
V	316	336	268	514
Cr	125	11	492	389
Ni	n.a.	17	n.a.	n.a.
Ga	18	14	17	12
Rb	17	18	17	5
Sr	576	476	287	208
Y	21	21	16	13
Zr	50	50	50	28
Th	0	2	2	0
U	1	1	0	4
Nb	n.a.	2	n.a.	n.a.
Ba	168	239	212	55
Pb	8	5	6	4
La	7	11	-6	5
Ce	4	7	4	-19
Pr	5	5	1	5
Nd	3	n.a.	n.a.	-3

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58927	58923	58924	58979
Unit	Skippers Fm.	Skippers Fm.	Skippers Fm.	Skippers Fm.
Member/Section	Hokuri Amphibolites	LSUC	LSUC	
Description	Fine grained dike(?)	Meta-pxite	Meta-gabbro	
SiO_2	48.74	46.13	45.91	49.69
TiO_2	0.59	0.19	0.17	0.58
Al_2O_3	14.88	9.27	14.98	15.91
Fe_2O_3	10.74	9.78	7.55	10.42
MnO	0.18	0.19	0.15	0.18
MgO	6.87	17.85	14.80	6.76
CaO	12.43	14.64	13.48	10.92
Na_2O	2.86	0.01	0.51	1.92
K_2O	0.14	0.00	0.00	0.50
P_2O_5	0.10	0.02	0.01	0.09
LOI	6.34	5.67	6.81	2.54
Total	103.87	103.75	104.37	99.51
Anhydrous				
SiO_2	50.45	47.43	47.37	51.72
TiO_2	0.61	0.20	0.18	0.60
Al_2O_3	15.40	9.53	15.46	16.56
FeO	8.50	7.69	5.95	8.29
Fe_2O_3	1.67	1.51	1.17	1.63
MnO	0.19	0.20	0.15	0.19
MgO	7.11	18.35	15.27	7.04
CaO	12.87	15.05	13.91	11.37
Na_2O	2.96	0.01	0.53	2.00
K_2O	0.14	0.00	0.00	0.52
P_2O_5	0.10	0.02	0.01	0.09
Normative mineralogy				
q	0.00	0.00	0.00	2.05
or	0.83	0.00	0.00	3.07
ab	25.02	0.08	4.48	16.89
an	28.31	25.94	39.78	34.66
ne	0.00	0.00	0.00	0.00
di_{wo}	14.54	20.25	12.14	8.79
di_{en}	7.91	14.37	8.73	4.81
di_{fs}	6.10	4.08	2.29	3.65
hyen	1.63	10.43	11.13	12.64
hy_{fs}	1.25	2.96	2.92	9.59
fo	5.66	14.50	12.61	0.00
fa	4.82	4.55	3.65	0.00
mt	2.43	2.19	1.70	2.36
il	1.16	0.38	0.34	1.15
ap	0.22	0.04	0.02	0.20
Trace elements (ppm)				
Sc	40	41	48	
V	323	118	115	
Cr	44	895	578	
Ni	n.a.	n.a.	n.a.	
Ga	14	11	12	
Rb	4	3	1	
Sr	375	112	230	
Y	16	7	6	
Zr	35	21	22	
Th	1	0	-2	
U	3	2	-1	
Nb	n.a.	n.a.	n.a.	
Ba	56	28	26	
Pb	5	6	4	
La	4	4	0	
Ce	-1	-27	-22	
Pr	6	5	4	
Nd	1	-9	-7	

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

Whole rock major and trace element analyses.

OU Number	58922	58928
Unit	Slip Hill Diorite	Twin Lakes Trond.
Member/Section		
Description		Trondjhemite
SiO_2	59.79	67.59
TiO_2	0.86	0.34
Al_2O_3	17.16	17.39
Fe_2O_3	6.77	2.50
MnO	0.11	0.07
MgO	2.64	0.81
CaO	5.28	2.91
Na_2O	3.40	6.33
K_2O	2.14	1.65
P_2O_5	0.17	0.09
LOI	4.69	4.40
Total	103.01	104.08
Anhydrous		
SiO_2	61.17	67.95
TiO_2	0.88	0.34
Al_2O_3	17.55	17.48
FeO	5.30	1.92
Fe_2O_3	1.04	0.38
MnO	0.11	0.07
MgO	2.70	0.81
CaO	5.40	2.93
Na_2O	3.48	6.36
K_2O	2.19	1.66
P_2O_5	0.17	0.09
Normative mineralogy		
q	13.93	16.04
or	12.93	9.80
ab	29.42	53.77
an	25.79	14.25
ne	0.00	0.00
di_{wo}	-0.05	-0.13
di_{en}	-0.02	-0.05
di_{fs}	0.00	0.00
hy_{en}	6.72	2.06
hy_{fs}	7.66	2.86
fo	0.00	0.00
fa	0.00	0.00
mt	1.51	0.55
il	1.67	0.65
ap	0.37	0.20
Trace elements (ppm)		
Sc	14	2
V	142	64
Cr	20	11
Ni	n.a.	n.a.
Ga	23	22
Rb	80	26
Sr	388	552
Y	23	12
Zr	225	141
Th	5	3
U	3	4
Nb	n.a.	n.a.
Ba	455	251
Pb	18	8
La	10	4
Ce	32	23
Pr	9	5
Nd	12	-1

n.a = not analysed or not applicable.
b.d.l. = below detection limit.

APPENDIX 2
MINERAL ANALYSES

The mineral analyses listed on the following pages were collected using a JEOL JXA-5A electron microprobe housed in the Geology Department, University of Otago and maintained by Dr. Y. Kawachi. Machine operating conditions were 15 kV and 2 nA (EDS) or 200 nA (WDS) sample current measured on MgO giving a beam size of 2-5 μ. Standards were a combination of oxides and minerals in general use at the time. WDS analyses were collected and reduced using the technique of Bence and Albee (1968) with a computer program written by Dr. Kawachi and modified by myself running on a DEC PDP 8/f computer. EDS analyses were collected and reduced using the technique of Reed and Ware (1975) with a program written by Ware (1981) and modified by Dr. Kawachi. Sodium values for clinopyroxenes analysed using EDS were estimated with reasonable accuracy by comparing counts collected concurrently for 100 seconds with a peaked wavelength spectrometer against a linear calibration of concentration/counts for a high An plagioclase analysed during the same session and MgO.

Clinopyroxene electron microprobe analyses.

OU Number	58930	58930	58932	58932
Remarks			Gporph clot 100µ from margin	Gporph clot core
n	1	1	1	1
SiO_2	52.45	53.02	50.42	53.05
TiO_2	0.39	0.31	0.33	0.00
Al_2O_3	1.19	1.13	3.27	1.51
FeO^*	9.88	9.94	7.31	3.43
MnO	0.46	0.48	0.30	0.20
MgO	14.19	14.11	16.43	18.82
CaO	20.34	19.94	21.16	22.14
Na_2O	0.00	0.00	0.34	0.29
Cr_2O_3	0.30	0.33	0.17	0.28
Total	99.20	99.26	99.73	99.72
Formula based on 6 oxygens				
Si	1.972	1.988	1.877	1.938
Al	0.053	0.050	0.144	0.065
Ti	0.011	0.009	0.009	0.000
Fe	0.311	0.312	0.228	0.105
Mn	0.015	0.015	0.009	0.006
Mg	0.796	0.789	0.912	1.025
Ca	0.820	0.801	0.844	0.867
Na	0.000	0.000	0.025	0.021
Cr	0.009	0.010	0.005	0.008
Total	3.986	3.973	4.052	4.035
Mg#	0.72	0.72	0.80	0.91
Wo	0.41	0.40	0.42	0.44
En	0.40	0.40	0.46	0.52
Fs	0.16	0.16	0.12	0.06

OU Number	58932	58932	58932	58932
Remarks	Gporph clot margin	Matrix 120µ core	Matrix 120µ margin	Matrix 150µ core
n	1	1	1	1
SiO_2	50.10	51.01	47.90	50.33
TiO_2	0.32	0.27	0.98	0.44
Al_2O_3	2.91	3.32	4.98	3.85
FeO^*	10.65	6.42	11.42	9.95
MnO	0.44	0.38	0.51	0.45
MgO	15.25	17.12	13.36	17.25
CaO	19.50	20.53	20.49	18.41
Na_2O	0.32	0.34	0.23	0.00
Cr_2O_3	0.00	0.43	0.00	0.00
Total	99.49	99.82	99.87	100.68
Formula based on 6 oxygens				
Si	1.890	1.885	1.817	1.861
Al	0.129	0.145	0.223	0.168
Ti	0.009	0.008	0.028	0.012
Fe	0.336	0.198	0.362	0.308
Mn	0.014	0.012	0.016	0.014
Mg	0.858	0.943	0.756	0.951
Ca	0.788	0.813	0.833	0.729
Na	0.023	0.024	0.017	0.000
Cr	0.000	0.013	0.000	0.000
Total	4.048	4.041	4.052	4.043
Mg#	0.72	0.83	0.68	0.76
Wo	0.40	0.41	0.42	0.37
En	0.43	0.47	0.38	0.48
Fs	0.18	0.11	0.19	0.16

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58932	58932	58932	58932
Remarks	Matrix 150μ margin	Mxst (001) 200μ from margin	Mxst (001) core	Mxst (001) margin
n	1	1	1	1
SiO_2	48.11	52.57	52.30	50.68
TiO_2	0.69	0.14	0.00	0.19
Al_2O_3	4.70	2.82	2.24	4.19
FeO^*	11.24	5.26	4.95	7.21
MnO	0.55	0.22	0.28	0.35
MgO	13.43	17.73	17.80	16.53
CaO	20.45	22.21	22.24	21.24
Na_2O	0.34	0.00	0.24	0.24
Cr_2O_3	0.00	0.40	0.26	0.00
Total	99.51	101.35	100.31	100.63
Formula based on 6 oxygens				
Si	1.830	1.904	1.915	1.865
Al	0.211	0.120	0.097	0.182
Ti	0.020	0.004	0.000	0.005
Fe	0.358	0.159	0.152	0.222
Mn	0.018	0.007	0.009	0.011
Mg	0.762	0.958	0.972	0.907
Ca	0.834	0.862	0.873	0.838
Na	0.025	0.000	0.017	0.017
Cr	0.000	0.011	0.008	0.000
Total	4.057	4.026	4.041	4.047
Mg#	0.68	0.86	0.86	0.80
Wo	0.42	0.43	0.44	0.42
En	0.38	0.48	0.49	0.46
Fs	0.19	0.08	0.08	0.12

OU Number	58932	58932	58932	58932
Remarks	Mxst 200μ from margin	Mxst core	Mxst margin	Phenoxst 600μ core
n	3	2	1	1
SiO_2	52.00	52.92	48.25	52.23
TiO_2	0.00	0.00	0.66	0.14
Al_2O_3	2.39	1.67	4.35	2.49
FeO^*	4.23	3.91	11.71	4.75
MnO	0.25	0.26	0.55	0.31
MgO	18.16	18.27	13.90	17.69
CaO	21.67	22.28	19.38	21.94
Na_2O	0.20	0.20	0.26	0.20
Cr_2O_3	0.71	0.46	0.00	0.31
Total	99.60	99.94	99.06	100.06
Formula based on 6 oxygens				
Si	1.911	1.935	1.842	1.914
Al	0.104	0.072	0.196	0.108
Ti	0.000	0.000	0.019	0.004
Fe	0.130	0.119	0.374	0.146
Mn	0.008	0.008	0.018	0.010
Mg	0.995	0.996	0.791	0.966
Ca	0.853	0.873	0.793	0.861
Na	0.014	0.014	0.019	0.014
Cr	0.021	0.013	0.000	0.009
Total	4.034	4.030	4.051	4.031
Mg#	0.88	0.89	0.68	0.87
Wo	0.43	0.44	0.40	0.43
En	0.50	0.50	0.40	0.49
Fs	0.07	0.06	0.20	0.08

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58932	58936	58955	58955
Remarks	Phenoxst 600μ margin	Phenoxst core	30μ matrix	Gporph 20μ from rim g-1
n	1	1	1	1
SiO_2	48.07	52.22	48.16	51.89
TiO_2	0.72	0.28	0.95	0.29
Al_2O_3	5.19	3.02	5.06	2.76
FeO^*	11.35	5.66	13.72	7.45
MnO	0.47	0.14	0.46	0.34
MgO	13.71	15.65	13.73	17.34
CaO	19.64	21.91	17.66	19.74
Na_2O	0.20	0.00	0.38	0.26
Cr_2O_3	0.00	0.17	0.00	0.28
Total	99.35	99.05	100.12	100.35
Formula based on 6 oxygens				
Si	1.826	1.933	1.825	1.908
Al	0.232	0.132	0.226	0.120
Ti	0.021	0.008	0.027	0.008
Fe	0.361	0.175	0.435	0.229
Mn	0.015	0.004	0.015	0.011
Mg	0.776	0.864	0.776	0.950
Ca	0.799	0.869	0.717	0.778
Na	0.015	0.000	0.028	0.019
Cr	0.000	0.005	0.000	0.008
Total	4.045	3.991	4.049	4.030
Mg#	0.68	0.83	0.64	0.81
Wo	0.40	0.44	0.36	0.39
En	0.39	0.43	0.39	0.48
Fs	0.19	0.09	0.23	0.12

OU Number	58955	58955	58955	58955
Remarks	Gporph core g-1	Gporph core g-1	Gporph core g-2	Gporph rim g-1
n	1	1	1	1
SiO_2	50.79	50.59	50.83	50.91
TiO_2	0.24	0.25	0.30	0.39
Al_2O_3	3.38	2.90	2.89	3.04
FeO^*	5.75	7.12	9.68	8.75
MnO	0.41	0.29	0.35	0.35
MgO	16.85	17.07	16.90	16.80
CaO	21.21	20.73	18.49	19.46
Na_2O	0.22	0.26	0.28	0.25
Cr_2O_3	0.34	0.00	0.14	0.15
Total	99.19	99.21	99.86	100.10
Formula based on 6 oxygens				
Si	1.886	1.888	1.894	1.889
Al	0.148	0.128	0.127	0.133
Ti	0.007	0.007	0.008	0.011
Fe	0.179	0.222	0.302	0.272
Mn	0.013	0.009	0.011	0.011
Mg	0.933	0.950	0.939	0.929
Ca	0.844	0.829	0.738	0.774
Na	0.016	0.019	0.020	0.018
Cr	0.010	0.000	0.004	0.004
Total	4.036	4.051	4.043	4.041
Mg#	0.84	0.81	0.76	0.77
Wo	0.42	0.42	0.37	0.39
En	0.47	0.48	0.47	0.47
Fs	0.10	0.12	0.16	0.14

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58955	58955	58955	58955
Remarks	Gporph rim g-1	Matrix 30μ	Mxst core	Mxst mid.
n	1	1	1	1
SiO_2	50.82	48.16	50.79	49.04
TiO_2	0.28	0.95	0.33	0.49
Al_2O_3	3.00	5.06	3.27	4.39
FeO^*	8.54	13.72	9.65	10.18
MnO	0.30	0.46	0.41	0.37
MgO	16.68	13.73	16.76	15.20
CaO	19.80	17.66	18.36	18.95
Na_2O	0.26	0.38	0.29	0.38
Cr_2O_3	0.15	0.00	0.13	0.00
Total	99.83	100.12	99.99	99.00
Formula based on 6 oxygens				
Si	1.891	1.825	1.888	1.854
Al	0.132	0.226	0.143	0.196
Ti	0.008	0.027	0.009	0.014
Fe	0.266	0.435	0.300	0.322
Mn	0.009	0.015	0.013	0.012
Mg	0.925	0.776	0.929	0.857
Ca	0.789	0.717	0.731	0.767
Na	0.019	0.028	0.021	0.028
Cr	0.004	0.000	0.004	0.000
Total	4.043	4.049	4.039	4.049
Mg#	0.78	0.64	0.76	0.73
Wo	0.40	0.36	0.37	0.39
En	0.46	0.39	0.47	0.43
Fs	0.14	0.23	0.16	0.17

OU Number	58955	58955	58955	58955
Remarks	Mxst rim	Phenoxst 100μ from rim	Phenoxst 50μ from rim	Phenoxst 60μ core
n	1	1	1	1
SiO_2	51.36	51.37	51.68	47.19
TiO_2	0.34	0.27	0.27	1.17
Al_2O_3	2.76	3.33	3.54	5.64
FeO^*	9.43	6.87	5.99	11.68
MnO	0.44	0.30	0.19	0.40
MgO	16.99	15.52	15.69	14.27
CaO	18.71	21.40	21.92	18.97
Na_2O	0.33	0.22	0.19	0.36
Cr_2O_3	0.00	0.18	0.43	0.00
Total	100.36	99.46	99.90	99.68
Formula based on 6 oxygens				
Si	1.901	1.908	1.905	1.790
Al	0.120	0.146	0.154	0.252
Ti	0.009	0.008	0.007	0.033
Fe	0.292	0.213	0.185	0.371
Mn	0.014	0.009	0.006	0.013
Mg	0.938	0.859	0.862	0.807
Ca	0.742	0.852	0.866	0.771
Na	0.024	0.016	0.014	0.026
Cr	0.000	0.005	0.013	0.000
Total	4.041	4.017	4.011	4.064
Mg#	0.76	0.80	0.82	0.69
Wo	0.37	0.43	0.44	0.39
En	0.47	0.43	0.43	0.41
Fs	0.15	0.11	0.10	0.19

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58955	58955	58955	58955
Remarks	Phenoxst 70μ core	Phenoxst 80μ core	Phenoxst core	Phenoxst core
n	1	1	1	1
SiO_2	48.08	47.51	51.95	51.58
TiO_2	0.73	0.90	0.30	0.34
Al_2O_3	5.24	5.54	2.29	2.58
FeO^*	11.87	11.51	8.06	6.99
MnO	0.38	0.48	0.37	0.23
MgO	14.41	14.91	15.64	15.87
CaO	17.84	17.65	20.58	21.17
Na_2O	0.37	0.34	0.14	0.14
Cr_2O_3	0.00	0.00	0.15	0.16
Total	98.92	98.84	99.48	99.06
Formula based on 6 oxygens				
Si	1.829	1.808	1.934	1.923
Al	0.235	0.249	0.101	0.113
Ti	0.021	0.026	0.008	0.010
Fe	0.378	0.366	0.251	0.218
Mn	0.012	0.015	0.012	0.007
Mg	0.817	0.846	0.868	0.882
Ca	0.727	0.720	0.821	0.846
Na	0.027	0.025	0.010	0.010
Cr	0.000	0.000	0.004	0.005
Total	4.046	4.055	4.010	4.014
Mg#	0.68	0.70	0.78	0.80
Wo	0.37	0.36	0.41	0.43
En	0.41	0.43	0.44	0.44
Fs	0.20	0.19	0.13	0.11

OU Number	58955	58955	58955	58955
Remarks	Phenoxst core	Phenoxst core	Phenoxst rim	Phenoxst rim
n	1	1	1	1
SiO_2	51.05	51.69	50.78	51.52
TiO_2	0.21	0.30	0.55	0.23
Al_2O_3	2.99	2.52	3.33	3.37
FeO^*	6.48	6.31	11.54	6.33
MnO	0.35	0.22	0.38	0.23
MgO	17.20	17.35	14.34	17.22
CaO	20.89	20.99	19.20	21.29
Na_2O	0.18	0.23	0.19	0.19
Cr_2O_3	0.22	0.17	0.00	0.25
Total	99.57	99.78	100.31	100.63
Formula based on 6 oxygens				
Si	1.892	1.908	1.900	1.887
Al	0.131	0.110	0.147	0.146
Ti	0.006	0.008	0.015	0.006
Fe	0.201	0.195	0.361	0.194
Mn	0.011	0.007	0.012	0.007
Mg	0.950	0.955	0.800	0.940
Ca	0.830	0.830	0.770	0.836
Na	0.013	0.016	0.014	0.013
Cr	0.006	0.005	0.000	0.000
Total	4.040	4.034	4.018	4.037
Mg#	0.83	0.83	0.69	0.83
Wo	0.42	0.42	0.39	0.42
En	0.48	0.48	0.40	0.47
Fs	0.11	0.10	0.19	0.10

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58955	58955	58955	58955
Remarks	Phenoxst rim	Phenoxst rim	Phenoxst rim	Phenoxst rim
n	1	1	1	1
SiO_2	50.39	47.52	47.22	48.07
TiO_2	0.33	1.03	1.02	1.05
Al_2O_3	3.35	5.44	5.73	5.62
FeO^*	7.89	13.02	12.68	12.26
MnO	0.33	0.42	0.52	0.43
MgO	16.74	14.37	14.79	15.08
CaO	20.04	17.16	16.76	17.41
Na_2O	0.18	0.33	0.38	0.36
Cr_2O_3	0.30	0.00	0.00	0.00
Total	99.55	99.29	99.10	100.28
Formula based on 6 oxygens				
Si	1.877	1.809	1.799	1.805
Al	0.147	0.244	0.257	0.249
Ti	0.009	0.029	0.029	0.030
Fe	0.246	0.415	0.404	0.385
Mn	0.010	0.014	0.017	0.014
Mg	0.930	0.816	0.840	0.844
Ca	0.800	0.700	0.684	0.701
Na	0.013	0.024	0.028	0.026
Cr	0.009	0.000	0.000	0.000
Total	4.042	4.051	4.058	4.054
Mg#	0.79	0.66	0.68	0.69
Wo	0.40	0.35	0.34	0.35
En	0.47	0.41	0.42	0.42
Fs	0.13	0.22	0.21	0.20

OU Number	58955	58955	58956	58956
Remarks	Phenoxst rim	Phenoxst70µ core	Matrix core	Matrix core
n	1	1	1	1
SiO_2	48.69	48.65	50.31	47.89
TiO_2	0.78	0.88	0.40	1.04
Al_2O_3	5.00	5.19	3.73	5.80
FeO^*	11.40	11.81	8.76	10.82
MnO	0.45	0.44	0.00	0.16
MgO	15.63	15.36	15.17	13.70
CaO	17.94	17.00	19.95	20.14
Na_2O	0.35	0.45	0.28	0.37
Cr_2O_3	0.00	0.20	0.00	0.00
Total	100.24	99.98	98.60	99.92
Formula based on 6 oxygens				
Si	1.824	1.826	1.894	1.805
Al	0.221	0.230	0.166	0.258
Ti	0.022	0.025	0.011	0.029
Fe	0.357	0.371	0.276	0.341
Mn	0.014	0.014	0.000	0.005
Mg	0.873	0.860	0.851	0.770
Ca	0.720	0.684	0.805	0.814
Na	0.025	0.033	0.020	0.027
Cr	0.000	0.006	0.000	0.000
Total	4.057	4.048	4.023	4.050
Mg#	0.71	0.70	0.76	0.69
Wo	0.36	0.34	0.40	0.41
En	0.44	0.43	0.43	0.39
Fs	0.19	0.19	0.14	0.17

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58956	58956	58956	58956
Remarks	Matrix core	Matrix rim	Matrix rim	Mxst core
n	1	1	1	1
SiO_2	48.79	49.31	48.43	51.10
TiO_2	0.78	0.69	0.63	0.31
Al_2O_3	5.91	3.75	4.06	3.58
FeO^*	9.55	10.65	9.90	6.31
MnO	0.00	0.00	0.00	0.00
MgO	13.94	13.35	13.33	15.88
CaO	20.72	20.90	20.70	22.34
Na_2O	0.29	0.35	0.31	0.22
Cr_2O_3	0.00	0.00	0.00	0.26
Total	99.98	99.00	97.36	100.00
Formula based on 6 oxygens				
Si	1.824	1.875	1.867	1.888
Al	0.261	0.168	0.185	0.156
Ti	0.022	0.020	0.018	0.009
Fe	0.299	0.339	0.319	0.195
Mn	0.000	0.000	0.000	0.000
Mg	0.777	0.757	0.766	0.875
Ca	0.830	0.851	0.855	0.884
Na	0.021	0.026	0.023	0.016
Cr	0.000	0.000	0.000	0.008
Total	4.034	4.035	4.034	4.030
Mg#	0.72	0.69	0.71	0.82
Wo	0.42	0.43	0.43	0.44
En	0.39	0.38	0.38	0.44
Fs	0.15	0.17	0.16	0.10

OU Number	58956	58956	58956	58956
Remarks	Mxst core	Mxst rim	Mxst rim	Phenoxst 600µ, 30µ form rim
n	1	1	1	1
SiO_2	50.90	51.21	49.54	52.51
TiO_2	0.28	0.48	0.60	0.00
Al_2O_3	3.95	3.55	4.21	2.27
FeO^*	5.98	7.50	9.58	3.88
MnO	0.00	0.00	0.00	0.00
MgO	15.20	15.29	13.88	16.59
CaO	22.64	21.47	21.30	23.01
Na_2O	0.25	0.24	0.27	0.19
Cr_2O_3	0.35	0.20	0.00	0.41
Total	99.55	99.94	99.38	98.86
Formula based on 6 oxygens				
Si	1.888	1.897	1.867	1.941
Al	0.173	0.155	0.187	0.099
Ti	0.008	0.013	0.017	0.000
Fe	0.185	0.232	0.302	0.120
Mn	0.000	0.000	0.000	0.000
Mg	0.840	0.844	0.780	0.914
Ca	0.900	0.852	0.860	0.911
Na	0.018	0.017	0.020	0.014
Cr	0.010	0.006	0.000	0.012
Total	4.022	4.018	4.033	4.011
Mg#	0.82	0.78	0.72	0.88
Wo	0.45	0.43	0.43	0.46
En	0.42	0.42	0.39	0.46
Fs	0.09	0.12	0.15	0.06

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58956	58956	58957	58957
Remarks	Phenoxst 600µ, rim	Phenoxst core 600µ		Matrix core
n	1	1	1	1
SiO_2	49.67	53.01	50.87	49.28
TiO_2	0.63	0.12	0.29	0.64
Al_2O_3	4.52	2.09	3.52	3.99
FeO^*	9.58	4.07	8.41	13.68
MnO	0.00	0.00	0.28	0.46
MgO	14.02	16.78	15.06	15.29
CaO	21.42	23.25	20.38	15.36
Na_2O	0.30	0.18	0.33	0.24
Cr_2O_3	0.00	0.26	0.16	0.00
Total	100.14	99.76	99.30	98.94
Formula based on 6 oxygens				
Si	1.858	1.943	1.902	1.873
Al	0.199	0.090	0.155	0.179
Ti	0.018	0.003	0.008	0.018
Fe	0.300	0.125	0.263	0.435
Mn	0.000	0.000	0.009	0.015
Mg	0.782	0.917	0.840	0.866
Ca	0.858	0.913	0.817	0.625
Na	0.022	0.013	0.024	0.018
Cr	0.000	0.008	0.005	0.000
Total	4.036	4.011	4.022	4.029
Mg#	0.72	0.88	0.76	0.67
Wo	0.43	0.46	0.41	0.31
En	0.39	0.46	0.42	0.44
Fs	0.15	0.06	0.14	0.23

OU Number	58957	58957	58957	58957
Remarks	Matrix core	Matrix core	Matrix core	Matrix core 50µ
n	1	1	1	1
SiO_2	48.10	50.31	48.30	47.82
TiO_2	1.00	0.55	0.75	1.13
Al_2O_3	5.85	3.75	5.23	5.47
FeO^*	11.55	10.28	11.16	12.45
MnO	0.34	0.40	0.37	0.40
MgO	13.42	14.83	13.54	12.57
CaO	18.84	19.12	19.19	19.05
Na_2O	0.24	0.20	0.26	0.26
Cr_2O_3	0.20	0.19	0.00	0.00
Total	99.54	99.63	98.80	99.15
Formula based on 6 oxygens				
Si	1.819	1.886	1.839	1.826
Al	0.261	0.166	0.235	0.246
Ti	0.028	0.016	0.021	0.032
Fe	0.365	0.322	0.355	0.398
Mn	0.011	0.013	0.012	0.013
Mg	0.757	0.829	0.768	0.715
Ca	0.763	0.768	0.783	0.779
Na	0.018	0.015	0.019	0.019
Cr	0.006	0.006	0.000	0.000
Total	4.028	4.020	4.032	4.029
Mg#	0.67	0.72	0.68	0.64
Wo	0.38	0.39	0.39	0.39
En	0.38	0.42	0.39	0.36
Fs	0.19	0.17	0.18	0.21

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58957	58957	58957	58957
Remarks	Matrix rim	Matrix rim	Matrix rim	Matrix rim
n	1	1	1	1
SiO_2	47.36	46.90	49.28	47.85
TiO_2	1.36	1.32	0.86	0.97
Al_2O_3	6.09	6.36	4.27	5.95
FeO^*	12.92	11.71	13.00	11.65
MnO	0.47	0.36	0.51	0.39
MgO	11.96	12.54	12.41	12.62
CaO	19.33	19.87	19.41	19.64
Na_2O	0.22	0.21	0.31	0.22
Cr_2O_3	0.00	0.00	0.12	0.00
Total	99.71	99.27	100.17	99.29
Formula based on 6 oxygens				
Si	1.804	1.789	1.866	1.819
Al	0.274	0.286	0.191	0.267
Ti	0.039	0.038	0.024	0.028
Fe	0.412	0.374	0.412	0.370
Mn	0.015	0.012	0.016	0.013
Mg	0.679	0.713	0.701	0.715
Ca	0.789	0.812	0.788	0.800
Na	0.016	0.016	0.023	0.016
Cr	0.000	0.000	0.004	0.000
Total	4.028	4.038	4.024	4.028
Mg#	0.62	0.66	0.63	0.66
Wo	0.40	0.41	0.40	0.40
En	0.34	0.36	0.35	0.36
Fs	0.21	0.19	0.22	0.19

OU Number	58957	58957	58957	58957
Remarks	In liquid inc.	Mxst core	Mxst core	Mxst core
n	1	1	1	1
SiO_2	49.79	53.71	53.99	51.60
TiO_2	0.41	0.00	0.13	0.33
Al_2O_3	5.61	1.07	1.20	2.60
FeO^*	8.54	3.06	3.27	7.64
MnO	0.32	0.29	0.20	0.29
MgO	14.69	17.35	17.28	15.36
CaO	20.21	22.73	22.75	20.88
Na_2O	0.37	0.30	0.29	0.30
Cr_2O_3	0.15	0.84	0.77	0.35
Total	100.09	99.35	99.88	99.35
Formula based on 6 oxygens				
Si	1.848	1.969	1.969	1.924
Al	0.246	0.046	0.052	0.114
Ti	0.011	0.000	0.004	0.009
Fe	0.265	0.094	0.100	0.238
Mn	0.010	0.009	0.006	0.009
Mg	0.813	0.949	0.939	0.854
Ca	0.804	0.893	0.889	0.834
Na	0.027	0.021	0.021	0.022
Cr	0.004	0.024	0.022	0.010
Total	4.029	4.006	4.001	4.015
Mg#	0.75	0.91	0.90	0.78
Wo	0.40	0.45	0.45	0.42
En	0.41	0.48	0.47	0.43
Fs	0.14	0.05	0.05	0.12

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58957	58957	58957	58957
Remarks	Mxst core	Mxst margin	Mxst margin	Phenoxst core
n	1	1	1	1
SiO_2	52.74	51.17	51.74	53.80
TiO_2	0.19	0.35	0.23	0.00
Al_2O_3	1.94	3.19	3.15	1.57
FeO^*	6.37	7.42	7.09	4.28
MnO	0.26	0.27	0.25	0.25
MgO	15.92	14.90	15.28	16.76
CaO	21.39	21.48	21.71	22.79
Na_2O	0.32	0.34	0.35	0.24
Cr_2O_3	0.50	0.13	0.19	0.34
Total	99.63	99.25	99.99	100.03
Formula based on 6 oxygens				
Si	1.950	1.911	1.915	1.966
Al	0.085	0.140	0.137	0.068
Ti	0.005	0.010	0.006	0.000
Fe	0.197	0.232	0.219	0.131
Mn	0.008	0.009	0.008	0.008
Mg	0.877	0.830	0.843	0.913
Ca	0.847	0.860	0.861	0.892
Na	0.023	0.025	0.025	0.017
Cr	0.015	0.004	0.006	0.010
Total	4.007	4.019	4.020	4.004
Mg#	0.82	0.78	0.79	0.87
Wo	0.43	0.43	0.43	0.45
En	0.44	0.42	0.42	0.46
Fs	0.10	0.12	0.11	0.07

OU Number	58957	58957	58957	58957
Remarks	Phenoxst core	Phenoxst core	Phenoxst core	Phenoxst core
n	1	1	1	1
SiO_2	53.82	52.25	53.50	53.58
TiO_2	0.13	0.29	0.15	0.00
Al_2O_3	1.49	2.79	1.49	1.55
FeO^*	4.41	6.59	4.12	4.15
MnO	0.16	0.21	0.25	0.21
MgO	16.74	15.77	16.91	16.95
CaO	22.69	21.89	22.89	22.74
Na_2O	0.29	0.34	0.28	0.27
Cr_2O_3	0.37	0.32	0.32	0.31
Total	100.10	100.45	99.91	99.76
Formula based on 6 oxygens				
Si	1.966	1.921	1.958	1.962
Al	0.064	0.121	0.064	0.067
Ti	0.004	0.008	0.004	0.000
Fe	0.135	0.203	0.126	0.127
Mn	0.005	0.007	0.008	0.007
Mg	0.912	0.864	0.923	0.926
Ca	0.888	0.862	0.898	0.892
Na	0.021	0.024	0.020	0.019
Cr	0.011	0.009	0.009	0.009
Total	4.004	4.018	4.011	4.009
Mg#	0.87	0.81	0.88	0.88
Wo	0.45	0.43	0.45	0.45
En	0.46	0.43	0.46	0.47
Fs	0.07	0.11	0.07	0.07

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58957	58957	58957	58957
Remarks	Phenoxst core	Phenoxst core	Phenoxst core	Phenoxst core 350µ
n	1	1	1	1
SiO_2	53.07	51.69	47.54	50.04
TiO_2	0.00	0.39	1.59	0.47
Al_2O_3	1.73	2.89	5.49	3.18
FeO^*	4.24	8.12	13.44	8.87
MnO	0.25	0.38	0.58	0.36
MgO	16.52	15.18	11.79	15.03
CaO	22.93	20.92	18.86	20.88
Na_2O	0.26	0.24	0.30	0.19
Cr_2O_3	0.28	0.00	0.00	0.00
Total	99.28	99.81	99.59	99.02
Formula based on 6 oxygens				
Si	1.957	1.921	1.817	1.887
Al	0.075	0.127	0.247	0.141
Ti	0.000	0.011	0.046	0.013
Fe	0.131	0.252	0.430	0.280
Mn	0.008	0.012	0.019	0.012
Mg	0.908	0.841	0.672	0.845
Ca	0.906	0.833	0.772	0.844
Na	0.019	0.017	0.022	0.014
Cr	0.008	0.000	0.000	0.000
Total	4.011	4.014	4.025	4.036
Mg#	0.87	0.77	0.61	0.75
Wo	0.46	0.42	0.39	0.42
En	0.46	0.42	0.34	0.42
Fs	0.07	0.13	0.23	0.15

OU Number	58957	58957	58957	58957
Remarks	Phenoxst core 500µ	Phenoxst margin	Phenoxst margin	Phenoxst margin
n	1	1	1	1
SiO_2	52.01	47.19	49.59	49.59
TiO_2	0.42	0.86	0.65	0.65
Al_2O_3	2.75	5.76	4.61	4.61
FeO^*	6.93	11.40	9.86	9.86
MnO	0.32	0.35	0.37	0.37
MgO	15.85	12.31	13.94	13.94
CaO	21.24	19.69	20.65	20.65
Na_2O	0.26	0.40	0.36	0.36
Cr_2O_3	0.31	0.00	0.00	0.00
Total	100.09	97.96	100.03	100.03
Formula based on 6 oxygens				
Si	1.919	1.821	1.858	1.858
Al	0.120	0.262	0.204	0.204
Ti	0.012	0.025	0.018	0.018
Fe	0.214	0.368	0.309	0.309
Mn	0.010	0.011	0.012	0.012
Mg	0.872	0.708	0.779	0.779
Ca	0.840	0.814	0.829	0.829
Na	0.019	0.030	0.026	0.026
Cr	0.009	0.000	0.000	0.000
Total	4.014	4.039	4.035	4.035
Mg#	0.80	0.66	0.72	0.72
Wo	0.42	0.41	0.42	0.42
En	0.44	0.36	0.39	0.39
Fs	0.11	0.19	0.16	0.16

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58957	58957	58957	58957
Remarks	Phenoxst margin	Phenoxst margin	Phenoxst margin	Phenoxst margin
n	1	1	1	1
SiO_2	47.66	47.25	47.27	47.92
TiO_2	0.95	1.10	0.98	0.78
Al_2O_3	5.69	6.24	6.18	5.45
FeO^*	11.42	12.17	11.87	10.56
MnO	0.35	0.24	0.37	0.43
MgO	12.78	12.10	12.18	13.03
CaO	20.11	19.75	19.99	19.77
Na_2O	0.32	0.36	0.44	0.40
Cr_2O_3	0.00	0.00	0.00	0.00
Total	99.28	99.21	99.28	98.34
Formula based on 6 oxygens				
Si	1.815	1.804	1.804	1.833
Al	0.255	0.281	0.278	0.246
Ti	0.027	0.032	0.028	0.022
Fe	0.364	0.389	0.379	0.338
Mn	0.011	0.008	0.012	0.014
Mg	0.726	0.689	0.693	0.743
Ca	0.821	0.808	0.818	0.810
Na	0.024	0.027	0.033	0.030
Cr	0.000	0.000	0.000	0.000
Total	4.042	4.037	4.045	4.036
Mg#	0.67	0.64	0.65	0.69
Wo	0.41	0.41	0.41	0.41
En	0.36	0.35	0.35	0.37
Fs	0.19	0.20	0.20	0.18

OU Number	58957	58957	58957	58957
Remarks	Phenoxst rim 350µ	Phenoxst rim 500µ	Phenoxst w/liq. inc. core	Phenoxst w/liq. inc. core
n	1	1	1	1
SiO_2	47.66	49.99	53.24	54.00
TiO_2	1.16	0.47	0.00	0.00
Al_2O_3	5.43	4.28	1.39	1.31
FeO^*	13.64	9.44	3.83	3.87
MnO	0.42	0.37	0.16	0.26
MgO	12.43	14.23	17.07	17.20
CaO	18.27	20.26	22.83	22.85
Na_2O	0.32	0.22	0.27	0.32
Cr_2O_3	0.00	0.00	0.67	0.52
Total	99.33	99.26	99.46	100.33
Formula based on 6 oxygens				
Si	1.823	1.879	1.957	1.966
Al	0.245	0.190	0.060	0.056
Ti	0.033	0.013	0.000	0.000
Fe	0.436	0.297	0.118	0.118
Mn	0.014	0.012	0.005	0.008
Mg	0.709	0.798	0.935	0.933
Ca	0.749	0.816	0.899	0.891
Na	0.024	0.016	0.019	0.023
Cr	0.000	0.000	0.019	0.015
Total	4.033	4.021	4.013	4.010
Mg#	0.62	0.73	0.89	0.89
Wo	0.38	0.41	0.45	0.45
En	0.36	0.40	0.47	0.47
Fs	0.23	0.16	0.06	0.06

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Clinopyroxene electron microprobe analyses.

OU Number	58957	58968	58968	58968
Remarks	Phenoxst, margin	Phenoxst, core, 450μ	Phenoxst, rim 450μ	Phenoxst, core, 1000μ
n	1	1	1	1
SiO_2	53.79	50.54	48.02	54.34
TiO_2	0.00	0.58	1.10	0.00
Al_2O_3	1.39	4.23	5.99	1.62
FeO^*	3.91	8.22	12.35	3.09
MnO	0.28	0.00	0.26	0.00
MgO	17.11	15.09	12.17	17.60
CaO	22.60	20.83	19.76	23.61
Na_2O	0.26	0.02	0.14	0.12
Cr_2O_3	0.56	0.00	0.00	0.42
Total	99.90	99.51	99.79	100.80
Formula based on 6 oxygens				
Si	1.966	1.882	1.820	1.961
Al	0.060	0.186	0.268	0.069
Ti	0.000	0.016	0.031	0.000
Fe	0.120	0.256	0.392	0.093
Mn	0.009	0.000	0.008	0.000
Mg	0.932	0.838	0.688	0.947
Ca	0.885	0.831	0.803	0.913
Na	0.018	0.001	0.010	0.008
Cr	0.016	0.000	0.000	0.012
Total	4.006	4.010	4.020	4.003
Mg#	0.89	0.77	0.64	0.91
Wo	0.44	0.42	0.40	0.46
En	0.47	0.42	0.35	0.48
Fs	0.06	0.13	0.20	0.05

OU Number	58968	59002	59002	59002
Remarks	Phenoxst, rim 1000μ	Step scan	Step scan	Step scan
n	1	2	2	2
SiO_2	54.04	49.94	50.65	51.08
TiO_2	0.00	0.47	0.46	0.16
Al_2O_3	1.59	3.58	2.84	1.84
FeO^*	2.94	7.19	8.86	5.74
MnO	0.00	0.15	0.27	0.16
MgO	17.72	15.20	15.06	16.26
CaO	23.36	22.75	21.36	23.77
Na_2O	0.07	0.23	0.30	0.19
Cr_2O_3	0.61	0.00	0.10	0.17
Total	100.33	99.51	99.90	99.37
Formula based on 6 oxygens				
Si	1.958	1.869	1.895	1.907
Al	0.068	0.158	0.125	0.081
Ti	0.000	0.013	0.013	0.004
Fe	0.089	0.225	0.277	0.179
Mn	0.000	0.005	0.009	0.005
Mg	0.957	0.848	0.840	0.905
Ca	0.907	0.912	0.856	0.951
Na	0.005	0.017	0.022	0.014
Cr	0.017	0.000	0.003	0.005
Total	4.002	4.047	4.039	4.052
Mg#	0.91	0.79	0.75	0.83
Wo	0.46	0.46	0.43	0.48
En	0.48	0.43	0.42	0.45
Fs	0.04	0.12	0.14	0.09

FeO^* is total iron as FeO. "n" indicates the number of analyses of a spot averaged in the reported analysis.

$$Wo = \frac{Ca}{Ca+Mg+Fe+Mn} \quad En = \frac{Mg}{Ca+Mg+Fe+Mn} \quad Fs = \frac{Fe+Mn}{Ca+Mg+Fe+Mn}$$

Plagioclase electron microprobe analyses.

OU Number	58932	58932	58932	58932
Remarks	µlite	µlite, 300µ long, core	µlite, 300µ long, margin	µlite, core
n	1	1	1	1
SiO_2	52.87	48.18	54.00	47.99
Al_2O_3	29.44	32.03	28.54	32.00
FeO*	1.02	1.24	0.88	1.15
CaO	11.98	14.99	10.62	15.40
Na_2O	4.86	2.92	5.61	2.87
K_2O	0.24	0.20	0.28	0.16
Total	100.41	99.56	99.93	99.57
Formula based on 32 oxygens				
Si	9.594	8.909	9.807	8.882
Al	6.298	6.983	6.111	6.982
Fe	0.155	0.192	0.134	0.178
Ca	2.329	2.970	2.067	3.054
Na	1.710	1.047	1.976	1.030
K	0.055	0.047	0.064	0.038
Total	20.141	20.148	20.159	20.163
$\frac{Ca}{Ca+Na+K}$	0.569	0.731	0.503	0.741

OU Number	58932	58932	58932	58932
Remarks	µlite, margin	µlite, core	µlite, margin	In "band"
n	1	1	1	1
SiO_2	52.66	48.73	52.83	53.77
Al_2O_3	29.46	32.47	30.63	29.37
FeO*	0.82	1.12	1.05	0.89
CaO	11.64	15.42	12.81	11.45
Na_2O	4.93	2.67	4.49	5.10
K_2O	0.28	0.15	0.25	0.29
Total	99.79	100.56	102.06	100.87
Formula based on 32 oxygens				
Si	9.601	8.910	9.448	9.688
Al	6.332	6.999	6.458	6.238
Fe	0.125	0.171	0.157	0.134
Ca	2.274	3.021	2.455	2.210
Na	1.743	0.947	1.557	1.782
K	0.065	0.035	0.057	0.066
Total	20.139	20.083	20.132	20.119
$\frac{Ca}{Ca+Na+K}$	0.557	0.755	0.603	0.545

OU Number	58932	58936	58955	58955
Remarks	In band	Grndmass	Grndmass core	µlite
n	1	1	1	1
SiO_2	53.77	48.25	56.07	54.94
Al_2O_3	29.37	31.68	28.16	28.84
FeO*	0.89	0.89	0.74	0.00
CaO	11.45	15.46	9.56	10.60
Na_2O	5.10	2.63	6.63	5.92
K_2O	0.29	0.10	0.41	0.35
Total	100.87	99.01	101.57	100.65
Formula based on 32 oxygens				
Si	9.688	8.954	9.997	9.866
Al	6.238	6.931	5.919	6.106
Fe	0.134	0.138	0.110	0.000
Ca	2.210	3.074	1.826	2.040
Na	1.782	0.946	2.292	2.061
K	0.066	0.024	0.093	0.080
Total	20.119	20.067	20.237	20.153
$\frac{Ca}{Ca+Na+K}$	0.545	0.760	0.434	0.488

"n" indicates the number of analyses of a spot averaged in the reported analysis.

Plagioclase electron microprobe analyses.

OU Number	58955	58955	58955	58956
Remarks	µlite	In Pl pse., high biref. core	In pse.	µlite
n	1	1	1	1
SiO_2	54.21	60.57	69.81	51.16
Al_2O_3	28.99	24.00	19.54	30.98
FeO*	0.00	0.00	0.00	0.00
CaO	11.34	3.63	0.17	13.63
Na_2O	5.35	8.21	11.20	3.69
K_2O	0.33	1.95	0.17	0.17
Total	100.22	98.36	100.89	99.63
Formula based on 32 oxygens				
Si	9.788	10.971	12.055	9.334
Al	6.171	5.125	3.978	6.664
Fe	0.000	0.000	0.000	0.000
Ca	2.194	0.705	0.031	2.665
Na	1.873	2.884	3.750	1.305
K	0.076	0.448	0.037	0.039
Total	20.102	20.132	19.851	20.008
$\frac{Ca}{Ca+Na+K}$	0.530	0.175	0.008	0.665

OU Number	58956	58956	58956	58956
Remarks	µlite	µlite core	µlite rim	µlite
n	1	1	1	1
SiO_2	49.63	50.30	54.11	53.58
Al_2O_3	31.95	31.19	29.01	29.40
FeO*	0.00	0.00	0.00	0.00
CaO	14.90	14.69	11.24	11.61
Na_2O	2.83	3.02	5.04	4.76
K_2O	0.00	0.14	0.22	0.24
Total	99.31	99.34	99.62	99.59
Formula based on 32 oxygens				
Si	9.103	9.224	9.806	9.723
Al	6.909	6.743	6.198	6.289
Fe	0.000	0.000	0.000	0.000
Ca	2.929	2.886	2.183	2.257
Na	1.007	1.074	1.771	1.675
K	0.000	0.033	0.051	0.055
Total	19.947	19.960	20.008	19.999
$\frac{Ca}{Ca+Na+K}$	0.744	0.723	0.545	0.566

OU Number	58956	58957	58957	58957
Remarks	µlite	µlite grndmass core	µlite grndmass margin	µlite grndmass core
n	1	1	1	1
SiO_2	54.01	57.92	51.51	53.31
Al_2O_3	30.02	27.01	29.86	29.04
FeO*	0.00	0.94	1.52	1.13
CaO	12.11	5.88	12.83	11.13
Na_2O	4.66	6.43	3.82	4.56
K_2O	0.25	1.86	0.30	0.50
Total	101.05	100.04	99.84	99.67
Formula based on 32 oxygens				
Si	9.669	10.407	9.434	9.716
Al	6.336	5.721	6.447	6.240
Fe	0.000	0.141	0.233	0.172
Ca	2.323	1.132	2.518	2.174
Na	1.618	2.240	1.357	1.612
K	0.057	0.424	0.070	0.116
Total	20.002	20.065	20.058	20.029
$\frac{Ca}{Ca+Na+K}$	0.581	0.298	0.638	0.557

"n" indicates the number of analyses of a spot averaged in the reported analysis.

Plagioclase electron microprobe analyses.

OU Number	58957	58957	58957	58957
Remarks	Grndmass core	Grndmass core	Grndmass rim	Grndmass core
n	1	1	1	1
SiO_2	50.67	54.07	55.07	51.30
Al_2O_3	30.58	28.86	27.39	30.32
FeO*	1.23	0.83	0.95	1.07
CaO	13.37	10.59	9.72	13.23
Na_2O	3.59	5.21	5.90	3.89
K_2O	0.14	0.34	0.25	0.10
Total	99.58	99.90	99.28	99.91
Formula based on 32 oxygens				
Si	9.301	9.804	10.032	9.375
Al	6.618	6.170	5.883	6.532
Fe	0.189	0.126	0.145	0.164
Ca	2.630	2.058	1.897	2.591
Na	1.278	1.832	2.084	1.378
K	0.033	0.078	0.058	0.023
Total	20.047	20.067	20.099	20.062
$\frac{Ca}{Ca+Na+K}$	0.667	0.519	0.470	0.649

OU Number	58957	59003	59003
Remarks	Grndmass rim	µphenoxst core	µphenoxst rim
n	1	2	2
SiO_2	54.75	47.36	46.50
Al_2O_3	27.98	32.80	33.02
FeO*	0.92	0.95	0.95
CaO	10.37	16.58	16.61
Na_2O	5.56	1.86	1.96
K_2O	0.29	0.08	0.07
Total	99.87	99.63	99.11
Formula based on 32 oxygens			
Si	9.931	8.743	8.645
Al	5.983	7.139	7.237
Fe	0.140	0.147	0.148
Ca	2.015	3.280	3.309
Na	1.955	0.666	0.707
K	0.067	0.019	0.016
Total	20.091	19.993	20.062
$\frac{Ca}{Ca+Na+K}$	0.499	0.827	0.821

"n" indicates the number of analyses of a spot averaged in the reported analysis.

Mantle Volcanics Formation alteration phases microprobe analyses

OU Number	58932	58932	58955	58955
Remarks	Grndmass	In Pl pse.	In grndmass	In Ol pse.
Phase	Chlorite	Epidote	Chlorite	Chlorite
SiO_2	31.36	34.36	24.28	25.22
TiO_2	0.00	0.20	0.00	0.00
Al_2O_3	13.30	2.33	16.20	18.03
FeO^*	11.59	25.32	22.15	27.72
MnO	0.21	0.40	0.00	0.00
MgO	30.09	0.49	16.15	14.72
CaO	0.00	32.33	0.00	0.00
Na_2O	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00
H_2O	12.08	1.56	10.26	10.92
Total	98.63	96.99	89.04	96.60
Formula based on:				
Oxygen	28	12.5	28	28
Si	6.229	3.303	5.675	5.541
Al	3.114	0.264	4.464	4.669
Ti	0.000	0.014	0.000	0.000
Fe	1.925	2.036	4.330	5.094
Mn	0.035	0.033	0.000	0.000
Mg	8.911	0.070	5.627	4.821
Ca	0.000	3.330	0.000	0.000
Na	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000
OH	16.000	1.000	16.000	16.000
Total	36.215	10.050	36.095	36.125

OU Number	58955	58955	58955	58955
Remarks	Grndmass	In grndmass	In Pl pse.	In Pl pse.
Phase	Chlorite	Chlorite	Clinozoisite	Clinozoisite
SiO_2	25.24	25.38	40.88	42.36
TiO_2	0.00	0.00	0.00	0.00
Al_2O_3	17.71	18.50	32.43	26.18
FeO^*	28.05	26.40	1.33	1.69
MnO	0.66	0.00	0.00	0.22
MgO	14.14	14.56	0.00	0.00
CaO	0.00	0.00	22.61	21.82
Na_2O	0.00	0.00	0.73	1.26
K_2O	0.00	0.00	0.00	0.00
H_2O	10.87	10.90	1.98	1.88
Total	96.66	95.74	99.96	95.39
Formula based on:				
Oxygen	28	28	12.5	12.5
Si	5.570	5.584	3.094	3.368
Al	4.606	4.799	2.894	2.454
Ti	0.000	0.000	0.000	0.000
Fe	5.177	4.858	0.084	0.112
Mn	0.122	0.000	0.000	0.014
Mg	4.652	4.776	0.000	0.000
Ca	0.000	0.000	1.834	1.859
Na	0.000	0.000	0.107	0.194
K	0.000	0.000	0.000	0.000
OH	16.000	16.000	1.000	1.000
Total	36.128	36.018	9.013	9.002

Mantle Volcanics Formation alteration phases microprobe analyses

OU Number	**58955**	**58955**	**58955**	**58956**
Remarks	In grndmass	In grndmass	In Pl pse.	In Ol pse.
Phase	Epidote	Epidote	Muscovite	Garnet
SiO_2	36.84	38.47	45.94	32.99
TiO_2	0.00	0.00	0.00	0.00
Al_2O_3	21.83	25.06	35.52	2.09
FeO^*	14.50	9.93	1.46	25.51
MnO	0.00	0.00	0.00	0.00
MgO	0.00	0.00	0.00	0.00
CaO	21.86	23.31	0.00	32.54
Na_2O	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	10.64	0.00
H_2O	1.77	1.85	4.43	0.00
Total	96.80	98.62	97.99	93.13
Formula based on:				
Oxygen	12.5	12.5	22	24
Si	3.115	3.112	6.212	6.290
Al	2.176	2.390	5.663	0.470
Ti	0.000	0.000	0.000	0.000
Fe	1.025	0.672	0.165	4.068
Mn	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000
Ca	1.981	2.020	0.000	6.648
Na	0.000	0.000	0.000	0.000
K	0.000	0.000	1.824	0.000
OH	1.000	1.000	4.000	0.000
Total	9.297	9.194	17.864	17.475

OU Number	**58956**	**58956**	**58957**	**58957**
Remarks	In Ol pse.	In Pl pse.	In grndmass inc.	Inc. in Cpx megaxst
Phase	Garnet	Muscovite	Actinolite	Actinolite
SiO_2	34.25	46.04	38.83	40.72
TiO_2	0.00	0.00	2.73	1.71
Al_2O_3	1.79	32.92	15.42	14.77
FeO^*	26.94	3.10	16.18	15.82
MnO	0.00	0.00	0.31	0.39
MgO	0.00	0.00	10.84	11.70
CaO	33.55	0.00	10.74	10.41
Na_2O	0.00	0.00	2.16	2.23
K_2O	0.00	10.92	0.31	0.18
H_2O	0.00	4.36	1.99	2.01
Total	96.53	97.34	99.51	99.94
Formula based on:				
Oxygen	24	22	23	23
Si	6.316	6.337	5.845	6.059
Al	0.389	5.342	2.737	2.591
Ti	0.000	0.000	0.309	0.191
Fe	4.155	0.357	2.037	1.969
Mn	0.000	0.000	0.040	0.049
Mg	0.000	0.000	2.433	2.596
Ca	6.629	0.000	1.732	1.660
Na	0.000	0.000	0.631	0.643
K	0.000	1.905	0.059	0.034
OH	0.000	4.000	2.000	2.000
Total	17.490	17.941	17.823	17.793

Mantle Volcanics Formation alteration phases microprobe analyses

OU Number	**58957**	**58957**	**58957**	**58957**
Remarks	Inc. in Cpx megaxst	In grndmass inc.	In Pl pse.	In Ol pse.
Phase	Actinolite	Actinolite	Clinozoisite	Garnet
SiO_2	41.36	48.91	41.00	35.56
TiO_2	1.53	0.33	0.18	0.45
Al_2O_3	14.47	11.00	30.83	9.23
FeO^*	14.33	8.32	3.30	17.05
MnO	0.32	0.32	0.00	0.38
MgO	12.81	9.45	0.00	0.44
CaO	10.15	18.39	22.71	33.19
Na_2O	1.98	1.47	0.83	0.00
K_2O	0.22	0.00	0.00	0.00
H_2O	2.02	2.09	1.97	0.00
Total	99.19	100.28	100.82	96.30
Formula based on:				
Oxygen	23	23	12.5	24
Si	6.141	7.021	3.112	6.143
Al	2.533	1.862	2.759	1.880
Ti	0.171	0.036	0.010	0.058
Fe	1.780	0.999	0.210	2.464
Mn	0.040	0.039	0.000	0.056
Mg	2.836	2.023	0.000	0.113
Ca	1.615	2.829	1.847	6.144
Na	0.570	0.409	0.122	0.000
K	0.041	0.000	0.000	0.000
OH	2.000	2.000	1.000	0.000
Total	17.728	17.217	9.060	16.859

OU Number	**58957**	**58957**
Remarks	In Pl pse.	In Pl pse.
Phase	Muscovite	Muscovite
SiO_2	47.60	50.87
TiO_2	0.00	0.29
Al_2O_3	32.28	3.52
FeO^*	2.66	8.41
MnO	0.13	0.28
MgO	1.26	15.06
CaO	0.00	20.38
Na_2O	0.20	0.00
K_2O	10.49	0.00
H_2O	4.45	4.36
Total	99.07	103.17
Formula based on:		
Oxygen	22	22
Si	6.410	6.996
Al	5.125	0.571
Ti	0.000	0.030
Fe	0.300	0.967
Mn	0.015	0.033
Mg	0.253	3.088
Ca	0.000	3.003
Na	0.052	0.000
K	1.791	0.000
OH	4.000	4.000
Total	17.945	18.689

Spinel electron microprobe analyses.

OU Number	58932	58932	58932	58932
Remarks	Core of inc. grain AN1	Cpx patch in megaxst	Inc. in Cp	Inc. in Cp
n	1	1	2	1
SiO_2	0.00	0.00	0.00	0.00
TiO_2	0.45	0.36	0.40	0.44
Al_2O_3	11.39	9.19	11.38	11.64
Fe_2O_3	12.28	12.25	12.12	12.05
FeO	11.36	14.61	11.63	11.31
MnO	0.38	0.59	0.34	0.50
MgO	14.60	12.06	14.42	14.57
Cr_2O_3	49.54	50.93	49.71	49.49
Formula based on 4 oxygens				
Si	0.000	0.000	0.000	0.000
Al	0.430	0.356	0.430	0.439
Ti	0.011	0.009	0.010	0.011
Fe^{2+}	0.304	0.402	0.312	0.302
Fe^{3+}	0.295	0.303	0.292	0.289
Mn	0.010	0.016	0.009	0.014
Mg	0.697	0.591	0.689	0.695
Cr	1.253	1.323	1.259	1.251
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.149	0.153	0.147	0.146
$\frac{Cr}{Cr+Al}$	0.745	0.788	0.745	0.740

OU Number	58932	58936	58936	58936
Remarks	Inc. in Cp, core		In contact with margin	In contact with margin
n	1	1	1	1
SiO_2	0.00	0.00	0.66	0.66
TiO_2	0.46	0.35	0.58	0.54
Al_2O_3	11.54	11.53	10.32	10.58
Fe_2O_3	11.95	8.36	7.46	8.01
FeO	12.06	11.28	18.37	12.23
MnO	0.39	0.00	0.00	0.00
MgO	14.16	14.90	10.85	14.86
Cr_2O_3	49.44	53.57	51.76	53.12
Formula based on 4 oxygens				
Si	0.000	0.000	0.022	0.021
Al	0.436	0.433	0.400	0.398
Ti	0.011	0.008	0.014	0.013
Fe^{2+}	0.323	0.301	0.505	0.327
Fe^{3+}	0.288	0.200	0.184	0.192
Mn	0.010	0.000	0.000	0.000
Mg	0.677	0.708	0.531	0.708
Cr	1.253	1.350	1.344	1.341
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.146	0.101	0.095	0.099
$\frac{Cr}{Cr+Al}$	0.742	0.757	0.771	0.771

Oxides have been normalised to 100% as most analyses were performed under machine conditions set for other minerals thus giving varying oxide totals.
"n" indicates the number of analyses of a spot averaged in the reported analysis.
Ferric iron was determined by the stoichiometric normalisation procedure of Finger (1972).

Spinel electron microprobe analyses.

OU Number	58936	58936	58936	58936
Remarks	In contact with matrix margin	In contact with matrix core	In Ol margin	In contact with grndmass
n	1	1	1	1
SiO_2	0.76	0.62	0.73	0.58
TiO_2	0.60	0.53	0.60	0.45
Al_2O_3	10.16	10.57	10.43	10.49
Fe_2O_3	7.36	8.09	8.12	8.65
FeO	22.55	12.02	13.44	11.64
MnO	0.00	0.00	0.00	0.00
MgO	8.21	14.96	14.14	15.11
Cr_2O_3	50.36	53.20	52.55	53.07
Formula based on 4 oxygens				
Si	0.026	0.020	0.024	0.019
Al	0.401	0.398	0.395	0.395
Ti	0.015	0.013	0.014	0.011
Fe^{2+}	0.631	0.321	0.361	0.311
Fe^{3+}	0.185	0.194	0.196	0.207
Mn	0.000	0.000	0.000	0.000
Mg	0.410	0.712	0.677	0.719
Cr	1.332	1.342	1.334	1.339
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.096	0.100	0.102	0.107
$\frac{Cr}{Cr+Al}$	0.769	0.771	0.772	0.772

OU Number	58936	58936	58936	58936
Remarks	Inc. in Ol	Inc. in Ol	Inc. in Ol	Inc. in Ol
n	1	1	1	1
SiO_2	0.65	0.63	0.69	0.66
TiO_2	0.45	0.50	0.57	0.45
Al_2O_3	10.75	10.66	10.54	10.46
Fe_2O_3	8.30	8.46	7.98	8.49
FeO	12.04	12.26	12.03	11.89
MnO	0.00	0.00	0.00	0.00
MgO	14.94	14.79	15.02	15.00
Cr_2O_3	52.87	52.69	53.18	53.05
Formula based on 4 oxygens				
Si	0.021	0.020	0.022	0.021
Al	0.404	0.402	0.396	0.394
Ti	0.011	0.012	0.014	0.011
Fe^{2+}	0.321	0.328	0.321	0.318
Fe^{3+}	0.199	0.203	0.191	0.204
Mn	0.000	0.000	0.000	0.000
Mg	0.710	0.705	0.714	0.714
Cr	1.333	1.331	1.341	1.339
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.103	0.105	0.099	0.105
$\frac{Cr}{Cr+Al}$	0.767	0.768	0.772	0.773

Oxides have been normalised to 100% as most analyses were performed under machine conditions set for other minerals thus giving varying oxide totals.
"n" indicates the number of analyses of a spot averaged in the reported analysis.
Ferric iron was determined by the stoichiometric normalisation procedure of Finger (1972).

Spinel electron microprobe analyses.

OU Number	58955	58955	58956	58956
Remarks	In Ol. pse., core	In Ol. pse., core	Lge. idm. S8.A1 core	large idio. core
n	1	1	1	1
SiO_2	0.00	0.00	0.00	0.00
TiO_2	3.15	2.51	0.34	0.34
Al_2O_3	8.23	7.86	10.05	10.06
Fe_2O_3	34.84	37.38	8.85	8.78
FeO	32.80	32.23	15.29	15.27
MnO	1.97	1.94	0.00	0.00
MgO	0.58	0.53	12.11	12.13
Cr_2O_3	18.42	17.55	53.35	53.41
Formula based on 4 oxygens				
Si	0.000	0.000	0.000	0.000
Al	0.352	0.337	0.387	0.388
Ti	0.086	0.069	0.008	0.008
Fe^{2+}	0.994	0.980	0.418	0.417
Fe^{3+}	0.949	1.022	0.217	0.216
Mn	0.061	0.060	0.000	0.000
Mg	0.031	0.029	0.590	0.591
Cr	0.528	0.505	1.379	1.380
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.519	0.548	0.110	0.109
$\frac{Cr}{Cr+Al}$	0.600	0.600	0.781	0.781

OU Number	58956	58957	58957	58957
Remarks	large idio. margin	inc olivine pse., core	inc. olivine pse., margin	inc. olivine pse., margin
n	1	1	1	1
SiO_2	0.00	0.00	0.00	0.00
TiO_2	0.44	0.37	0.44	0.47
Al_2O_3	9.11	9.42	10.47	9.97
Fe_2O_3	10.32	10.86	11.33	11.55
FeO	19.99	14.21	14.64	14.43
MnO	0.31	0.60	0.52	0.38
MgO	8.79	12.36	12.27	12.47
Cr_2O_3	51.04	52.19	50.32	50.74
Formula based on 4 oxygens				
Si	0.000	0.000	0.000	0.000
Al	0.361	0.363	0.403	0.384
Ti	0.011	0.009	0.011	0.012
Fe^{2+}	0.562	0.389	0.399	0.394
Fe^{3+}	0.261	0.267	0.278	0.283
Mn	0.009	0.017	0.014	0.011
Mg	0.440	0.603	0.597	0.607
Cr	1.356	1.351	1.298	1.310
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.132	0.135	0.140	0.143
$\frac{Cr}{Cr+Al}$	0.790	0.788	0.763	0.773

Oxides have been normalised to 100% as most analyses were performed under machine conditions set for other minerals thus giving varying oxide totals.
"n" indicates the number of analyses of a spot averaged in the reported analysis.
Ferric iron was determined by the stoichiometric normalisation procedure of Finger (1972).

Spinel electron microprobe analyses.

OU Number	58957	58957	58957	58957
Remarks	Grndmass	Grndmass	Grndmass	Grndmass
n	1	1	1	1
SiO_2	0.00	0.00	0.00	0.00
TiO_2	8.98	7.38	6.45	6.61
Al_2O_3	6.06	6.73	6.32	5.71
Fe_2O_3	40.43	39.06	38.12	38.17
FeO	44.53	46.83	49.10	49.52
MnO	0.00	0.00	0.00	0.00
MgO	0.00	0.00	0.00	0.00
Cr_2O_3	0.00	0.00	0.00	0.00
Formula based on 4 oxygens				
Si	0.000	0.000	0.000	0.000
Al	0.264	0.292	0.276	0.250
Ti	0.250	0.205	0.179	0.185
Fe^{2+}	1.250	1.205	1.179	1.185
Fe^{3+}	1.237	1.298	1.365	1.381
Mn	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000
Cr	0.000	0.000	0.000	0.000
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.824	0.816	0.832	0.847
$\frac{Cr}{Cr+Al}$	0.000	0.000	0.000	0.000

OU Number
Remarks
n
SiO_2
TiO_2
Al_2O_3
Fe_2O_3
FeO
MnO
MgO
Cr_2O_3
Formula based on 4 oxygens
Si
Al
Ti
Fe^{2+}
Fe^{3+}
Mn
Mg
Cr
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$
$\frac{Cr}{Cr+Al}$

Oxides have been normalised to 100% as most analyses were performed under machine conditions set for other minerals thus giving varying oxide totals.
"n" indicates the number of analyses of a spot averaged in the reported analysis.
Ferric iron was determined by the stoichiometric normalisation procedure of Finger (1972).

Spinel electron microprobe analyses.

OU Number	58932	58936	58955	58955
Remarks	Grndmass	Grndmass	In Ol. pse.	Grndmass
n	1	1	1	1
SiO_2	0.00	0.94	0.00	0.00
TiO_2	3.42	6.62	6.37	10.25
Al_2O_3	4.33	6.40	5.39	2.85
Fe_2O_3	39.60	39.54	37.05	41.05
FeO	51.88	46.51	48.52	45.85
MnO	0.13	0.00	0.00	0.00
MgO	0.52	0.00	0.56	0.00
Cr_2O_3	0.13	0.00	2.10	0.00
Formula based on 4 oxygens				
Si	0.000	0.034	0.000	0.000
Al	0.340	0.278	0.235	0.126
Ti	0.171	0.183	0.177	0.290
Fe^{2+}	1.113	1.218	1.146	1.290
Fe^{3+}	1.310	1.287	1.349	1.295
Mn	0.007	0.000	0.000	0.000
Mg	0.052	0.000	0.031	0.000
Cr	0.007	0.000	0.061	0.000
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.791	0.823	0.820	0.911
$\frac{Cr}{Cr+Al}$	0.019	0.000	0.207	0.000

OU Number	58955	58956	58956	58957
Remarks	Grndmass	In rim of Cpx	In grndmass	In grndmass inc.
n	1	1	1	1
SiO_2	0.00	0.00	0.00	0.00
TiO_2	7.07	11.45	12.74	4.16
Al_2O_3	6.41	5.48	2.93	4.28
Fe_2O_3	38.71	42.63	43.38	35.63
FeO	47.81	40.44	40.95	55.94
MnO	0.00	0.00	0.00	0.00
MgO	0.00	0.00	0.00	0.00
Cr_2O_3	0.00	0.00	0.00	0.00
Formula based on 4 oxygens				
Si	0.000	0.000	0.000	0.000
Al	0.279	0.239	0.129	0.189
Ti	0.197	0.318	0.359	0.117
Fe^{2+}	1.197	1.318	1.359	1.117
Fe^{3+}	1.328	1.124	1.153	1.576
Mn	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000
Cr	0.000	0.000	0.000	0.000
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.826	0.825	0.899	0.893
$\frac{Cr}{Cr+Al}$	0.000	0.000	0.000	0.000

Oxides have been normalised to 100% as most analyses were performed under machine conditions set for other minerals thus giving varying oxide totals.
"n" indicates the number of analyses of a spot averaged in the reported analysis.
Ferric iron was determined by the stoichiometric normalisation procedure of Finger (1972).

Spinel electron microprobe analyses.

OU Number	58957	58966	58968
Remarks	Inc. in Cp megaxst	in Ol pse.	In Ol. pse.
n	2	2	1
SiO_2	0.00	0.00	0.00
TiO_2	0.00	0.68	0.74
Al_2O_3	9.01	11.17	12.08
Fe_2O_3	14.79	10.52	11.15
FeO	21.55	15.70	13.92
MnO	0.00	0.00	0.00
MgO	7.66	12.15	13.33
Cr_2O_3	46.99	49.79	48.78
Formula based on 4 oxygens			
Si	0.000	0.000	0.000
Al	0.361	0.429	0.457
Ti	0.000	0.017	0.018
Fe^{2+}	0.612	0.427	0.374
Fe^{3+}	0.377	0.257	0.269
Mn	0.000	0.000	0.000
Mg	0.388	0.589	0.638
Cr	1.262	1.281	1.238
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.189	0.131	0.137
$\frac{Cr}{Cr+Al}$	0.778	0.749	0.730

OU Number	59002	58932	58932	58932
Remarks	Grndmass	Inc. margin of Cpx	Inc. margin of Cpx	Grndmass
n	2	1	1	1
SiO_2	0.59	0.00	0.00	0.00
TiO_2	15.77	6.00	4.99	2.89
Al_2O_3	3.39	5.14	6.49	3.95
Fe_2O_3	46.79	35.82	35.42	39.23
FeO	33.47	51.59	52.01	53.25
MnO	0.00	0.17	0.23	0.16
MgO	0.00	0.97	0.73	0.41
Cr_2O_3	0.00	0.31	0.12	0.11
Formula based on 4 oxygens				
Si	0.022	0.000	0.000	0.000
Al	0.148	0.224	0.282	0.335
Ti	0.439	0.167	0.138	0.157
Fe^{2+}	1.448	1.108	1.090	1.103
Fe^{3+}	0.931	1.434	1.439	1.345
Mn	0.000	0.005	0.007	0.010
Mg	0.000	0.054	0.040	0.044
Cr	0.000	0.009	0.004	0.006
$\frac{Fe^{3+}}{Fe^{3+}+Al+Cr}$	0.863	0.860	0.835	0.797
$\frac{Cr}{Cr+Al}$	0.000	0.039	0.012	0.018

Oxides have been normalised to 100% as most analyses were performed under machine conditions set for other minerals thus giving varying oxide totals.
"n" indicates the number of analyses of a spot averaged in the reported analysis.
Ferric iron was determined by the stoichiometric normalisation procedure of Finger (1972).

Skippers Formation microprobe analyses

OU Number	59005	59005	59005	59005
Remarks	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist
Phase	Actinolite	Actinolite	Actinolite	Actinolite
SiO_2	56.52	56.28	56.17	56.05
TiO_2	0.00	0.00	0.00	0.00
Al_2O_3	0.16	0.66	0.68	0.48
FeO^*	11.49	10.56	11.29	11.61
MnO	0.10	0.00	0.00	0.00
MgO	17.40	17.54	17.37	16.92
CaO	13.04	13.02	12.96	12.78
Na_2O	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00
Cr_2O_3	0.00	0.20	0.00	0.00
H_2O	2.12	2.12	2.12	2.11
Total	100.83	100.38	100.59	99.95
Formula based on:				
Oxygen	23	23	23	23
Si	7.979	7.946	7.937	7.978
Al	0.027	0.110	0.113	0.081
Ti	0.000	0.000	0.000	0.000
Fe	1.357	1.247	1.334	1.382
Mn	0.012	0.000	0.000	0.000
Mg	3.662	3.692	3.659	3.591
Ca	1.972	1.970	1.962	1.949
Na	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000
Cr	0.000	0.022	0.000	0.000
OH	2.000	2.000	2.000	2.000
Total	17.008	16.988	17.006	16.981

OU Number	59005	59005	59005	59005
Remarks	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist
Phase	Actinolite	Actinolite	Actinolite	Chlorite
SiO_2	55.99	55.30	54.08	27.42
TiO_2	0.00	0.00	0.00	0.00
Al_2O_3	0.70	0.88	1.20	18.85
FeO^*	11.05	11.47	8.12	22.35
MnO	0.00	0.20	0.00	0.17
MgO	17.16	16.66	16.98	0.35
CaO	12.89	12.75	12.68	18.72
Na_2O	0.00	0.00	0.18	0.00
K_2O	0.00	0.00	0.00	0.00
Cr_2O_3	0.15	0.00	0.18	0.47
H_2O	2.11	2.09	2.04	10.98
Total	100.05	99.35	95.46	99.31
Formula based on:				
Oxygen	23	23	23	28
Si	7.948	7.929	7.955	5.991
Al	0.117	0.149	0.208	4.856
Ti	0.000	0.000	0.000	0.000
Fe	1.312	1.375	0.999	4.085
Mn	0.000	0.024	0.000	0.031
Mg	3.632	3.561	3.724	0.114
Ca	1.961	1.959	1.999	4.383
Na	0.000	0.000	0.051	0.000
K	0.000	0.000	0.000	0.000
Cr	0.017	0.000	0.021	0.081
OH	2.000	2.000	2.000	16.000
Total	16.985	16.997	16.956	35.542

Skippers Formation microprobe analyses

OU Number	59005	59005	59005	59005
Remarks	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist
Phase	Chlorite	Chlorite	Chlorite	Epidote
SiO_2	27.24	27.22	26.98	38.53
TiO_2	0.00	0.00	0.00	25.91
Al_2O_3	19.95	19.50	20.03	0.17
FeO^*	0.97	22.82	22.65	9.74
MnO	0.38	0.32	0.40	0.00
MgO	18.53	18.36	18.21	0.00
CaO	0.00	0.00	0.00	23.75
Na_2O	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00
Cr_2O_3	0.27	0.34	0.00	0.00
H_2O	10.18	11.65	11.63	1.80
Total	77.52	100.21	99.90	99.90
Formula based on:				
Oxygen	28	28	28	12.5
Si	6.418	5.602	5.563	3.212
Al	5.542	4.731	4.869	0.017
Ti	0.000	0.000	0.000	1.625
Fe	0.191	3.928	3.906	0.679
Mn	0.076	0.056	0.070	0.000
Mg	6.510	5.634	5.598	0.000
Ca	0.000	0.000	0.000	2.122
Na	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000
Cr	0.050	0.055	0.000	0.000
OH	16.000	16.000	16.000	1.000
Total	34.787	36.006	36.005	8.655

OU Number	59005	59006	59006	59006
Remarks	Blastophyric greenschist	Meta-pyroxenite	Meta-pyroxenite	Meta-pyroxenite
Phase	Epidote	Chlorite	Actinolite	Clinopyroxene
SiO_2	37.54	26.96	53.30	50.57
TiO_2	0.00	0.00	0.00	0.11
Al_2O_3	21.92	22.05	2.04	2.59
FeO^*	15.01	16.44	9.64	4.74
MnO	0.00	0.24	0.20	0.00
MgO	0.00	24.51	20.35	18.43
CaO	23.48	0.00	12.18	23.15
Na_2O	0.00	0.00	1.17	0.11
K_2O	0.00	0.00	0.00	0.00
Cr_2O_3	0.00	0.00	0.00	0.16
H_2O	1.82	12.28	2.12	0.00
Total	99.77	102.48	101.00	99.86
Formula based on:				
Oxygen	12.5	28	23	6
Si	3.096	5.264	7.522	1.868
Al	2.132	5.076	0.339	0.113
Ti	0.000	0.000	0.000	0.003
Fe	1.035	2.685	1.138	0.146
Mn	0.000	0.040	0.024	0.000
Mg	0.000	7.135	4.282	1.015
Ca	2.075	0.000	1.842	0.916
Na	0.000	0.000	0.320	0.008
K	0.000	0.000	0.000	0.000
Cr	0.000	0.000	0.000	0.005
OH	1.000	16.000	2.000	0.000
Total	9.339	36.200	17.468	4.074

Skippers Formation microprobe analyses

OU Number	59006	59007	59007	59007
Remarks	Meta-pyroxenite	Massive greenschist	Massive greenschist	Massive greenschist
Phase	Clinopyroxene	Actinolite	Actinolite	Chlorite
SiO_2	50.07	55.15	53.80	27.40
TiO_2	0.24	0.00	0.00	0.00
Al_2O_3	3.01	1.01	1.33	20.06
FeO^*	5.67	14.12	14.68	21.36
MnO	0.00	0.29	0.26	0.42
MgO	18.03	14.58	13.90	18.19
CaO	22.42	11.71	12.06	0.00
Na_2O	0.28	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00
Cr_2O_3	0.11	0.00	0.00	0.00
H_2O	0.00	2.07	2.03	11.62
Total	99.83	98.93	98.06	99.05
Formula based on:				
Oxygen	6	23	23	28
Si	1.856	8.007	7.927	5.658
Al	0.132	0.173	0.231	4.883
Ti	0.007	0.000	0.000	0.000
Fe	0.176	1.714	1.809	3.689
Mn	0.000	0.036	0.032	0.073
Mg	0.996	3.156	3.054	5.600
Ca	0.890	1.822	1.904	0.000
Na	0.020	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000
Cr	0.003	0.000	0.000	0.000
OH	0.000	2.000	2.000	16.000
Total	4.080	16.907	16.957	35.902

OU Number	59007	59007	59007	59007
Remarks	Massive greenschist	Massive greenschist	Massive greenschist	Massive greenschist
Phase	Epidote	Epidote	Muscovite	Albite
SiO_2	41.27	39.40	47.40	69.46
TiO_2	0.00	0.00	0.00	0.00
Al_2O_3	31.31	28.24	35.45	19.52
FeO^*	2.32	6.48	0.41	0.00
MnO	0.15	0.00	0.00	0.00
MgO	0.00	0.00	0.00	0.00
CaO	23.61	23.73	0.00	0.00
Na_2O	0.00	0.00	0.00	11.89
K_2O	0.00	0.00	11.17	0.16
Cr_2O_3	0.00	0.00	0.00	0.00
H_2O	1.98	1.91	4.50	0.00
Total	100.64	99.76	98.93	101.03
Formula based on:				
Oxygen	12.5	12.5	22	32
Si	3.122	3.086	6.322	12.011
Al	2.792	2.608	5.574	3.979
Ti	0.000	0.000	0.000	0.000
Fe	0.147	0.425	0.046	0.000
Mn	0.010	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000
Ca	1.914	1.992	0.000	0.000
Na	0.000	0.000	0.000	3.987
K	0.000	0.000	1.889	0.035
Cr	0.000	0.000	0.000	0.000
OH	1.000	1.000	4.000	0.000
Total	8.983	9.111	17.831	20.012

Skippers Formation microprobe analyses

OU Number	59008	59008	59008	59008
Remarks	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist
Phase	Actinolite	Actinolite	Actinolite	Chromite
SiO_2	57.39	56.53	54.64	0.00
TiO_2	0.00	0.00	0.00	0.00
Al_2O_3	0.49	1.32	3.69	6.82
FeO^*	9.70	11.33	11.41	37.30
MnO	0.00	0.00	0.00	0.00
MgO	17.80	16.86	15.95	2.97
CaO	12.79	12.20	12.48	0.00
Na_2O	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00
Cr_2O_3	0.00	0.00	0.00	52.46
H_2O	2.14	2.13	2.12	0.00
Total	100.31	100.37	100.29	100.53
Formula based on:				
Oxygen	23	23	23	4
Si	8.048	7.973	7.734	0.000
Al	0.081	0.219	0.616	0.293
Ti	0.000	0.000	0.000	0.000
Fe	1.138	1.336	1.351	1.135
Mn	0.000	0.000	0.000	0.000
Mg	3.722	3.545	3.366	0.161
Ca	1.922	1.844	1.893	0.000
Na	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000
Cr	0.000	0.000	0.000	1.509
OH	2.000	2.000	2.000	0.000
Total	16.911	16.918	16.959	3.099

OU Number	59008	59008	59008	59008
Remarks	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist	Blastophyric greenschist
Phase	Chlorite	Muscovite	Muscovite	Muscovite
SiO_2	27.81	51.28	50.97	49.43
TiO_2	0.00	0.00	0.00	0.00
Al_2O_3	19.63	27.41	25.90	24.08
FeO^*	19.80	2.81	4.24	4.71
MnO	0.00	0.00	0.00	0.00
MgO	18.61	2.57	2.68	2.46
CaO	0.00	0.00	0.00	0.00
Na_2O	0.00	0.00	0.00	0.00
K_2O	0.00	10.89	10.82	10.61
Cr_2O_3	0.00	0.19	0.00	3.54
H_2O	11.53	4.48	4.42	4.36
Total	97.38	99.63	99.03	99.19
Formula based on:				
Oxygen	28	22	22	22
Si	5.784	6.863	6.914	6.796
Al	4.813	4.325	4.142	3.903
Ti	0.000	0.000	0.000	0.000
Fe	3.444	0.315	0.481	0.542
Mn	0.000	0.000	0.000	0.000
Mg	5.770	0.513	0.542	0.504
Ca	0.000	0.000	0.000	0.000
Na	0.000	0.000	0.000	0.000
K	0.000	1.848	1.861	1.849
Cr	0.000	0.020	0.000	0.385
OH	16.000	4.000	4.000	4.000
Total	35.811	17.884	17.940	17.980

APPENDIX 3
COMPUTER PROGRAMMES

During the course of research for this thesis I have developed or modified many computer and programmable calculator (HP-41C) programmes for data analysis, recording and translation. Most of this work has been done in the Excel™, Microsoft BASIC (interpreted) and ZBasic (compiled) environments on the Apple Macintosh™ computer, but much initial work (not documented here) was performed in FORTRAN on the DEC PDP-11. Only one of the programmes written and/or modified for operation of the electron microprobe on the PDP-8/f computer is included here as this computer broke down and was scrapped before updated source listings were printed.

There is little or no documentation with these programs as it would take months to document them to a commercial standard. The main purposes for listing them here are to record of some of the work which has gone into this thesis in the background which would otherwise be transparent to the casual reader and to provide a library of routines and procedures for other programmers.

The programmes written using Excel™ macro controlled spreadsheets and ZBasic compiled applications with installed resources are difficult to fully document in the textual environment of this thesis, but have been listed here for the reference of other programmers. All the programmes, with the exception of those for the HP-41C, are in machine readable form on disk available from the Curator, Department of Geology, University of Otago. All of the programmes are copyright 1988, H.R. Ballard and acknowledgement must be made in any published or unpublished work in which they are used whole or in part.

EQUIL - A PROGRAMME FOR THE MODELING OF LOW PRESSURE DIFFERENTIATION PROCESSES IN NATURAL MAFIC MAGMA BODIES (NIELSEN 1985).

Environment: Excel™, version 1.05 or greater
Installed resources: n.a.

This programme was originally written and the source listing published in FORTRAN. An initial attempt was made to translate it to a compiled BASIC but there were so many typographical errors and omissions in the published listing that it seemed better to completely re-write it for the Excel™ environment using the original ideas. This approach had several advantages:

- Uncomplicated input/output design.

- Iteration routines calculate all composition-T relationships simultaneously and the maximum can be determined easily.
- Array operations can be performed with simple, usually single instructions.
- Built-in database routines allow quick analysis of programme output without the need to re-enter data or translate formats.
- Visual display of parameters as calculation proceeds.
- The programme can be stopped at any time, parameters changed and then re-started.
- Model parameters can be easily programmed to change in complex ways based on results generated at each stage of the programme.

The programme was tested using experimental results from Grove and Bryan (1983) and Brown and Schairer (1968) and found to be in quite good agreement (see Appendix 4).

The spinel crystallisation portion of the programme gave unrealistic results and was deemed unnecessary for the scope of this work and disabled. As the example output from the published programme did not include a spinel phase, it is impossible to know whether this portion of the programme actually worked in the original. There are some parts of the programme that do not work at the time of writing, such as the calculation of total per cent crystallised, which do not affect other results but in themselves are meaningless. It is hoped that these parts will be de-bugged in future work.

The Excel™ programme consists of four worksheets and output is sent to a user defined fifth. These are the input form (EQ.INPUT), the output form (EQ.OUTPUT.ROW), the "scratch" sheet (EQ.SCRATCH) which performs most of the calculations and the controlling macro sheet (EQ.MACRO) which controls all the other sheets and in which many of the large array operations are performed. All of these worksheets are documented below with the values for defined names and cell contents which were in the sheets when they were referenced. These values would obviously change on running the programme again.

The human interface to the programme was not developed to a great deal because of time constraints. It is a complicated programme and undocumented except for these few pages, but there are many programming nuances undocumented in the EXCEL™ manuals which may be of use to other programmers.

Cross reference of Excel file EQ.INPUT

Names with cell references

R8C3:R8C4	Al2O3
R14C6	Assim.
R6C4:R15C4	Assim._comp.
R12C3:R12C4	CaO
R8C6:R8C7	Cpx
R15C3:R15C4	Cr2O3
R15C6	Erupt
R6C7:R11C7	Exc.
R10C3:R10C4	Fe2O3
R9C3:R9C4	FeO
R6C6:R11C6	Frac._F

R13C5	"Recharge"
R14C2	"K2O"
R14C3	0.54
R14C5	"Assim."
R15C2	"Cr2O3"
R15C5	"Erupt"
R16C3	"Solidus T "
R16C5	"Decrement factor"
R16C6	0.00025
R17C3	1000
R17C5	"Report factor"
R17C6	0.002

Cross reference of Excel file EQ.SCRATCH

Names with cell references

R4C5:R4C10	Al2O3
R11C1	ALUM
R4C12	B
R4C14	Bcpx
R24C13	Bspn
R13C12	CAM2
R13C14	CAM2cpx
R8C5:R8C10	CaO
R33C3:R42C3	Clinopx.
R17C1:R17C4	Cp
R22C4:R31C4	Cpx
R5C14	CPXAL
R19C14	CPXCA
R6C14	CPXCR
R18C14	CPXFE
R20C14	CPXMG
R7C14	CPXTI
R2C14	CPXTP
R11C5:R11C10	Cr2O3
R19C6	Crystalised
R15C2:R20C2	CUM
R17C12	D
R17C14	Dcpx
R26C15	Dilm
R8C12	DIOP
R8C14	DIOPcpx
R17C8	Dpla
R30C13	Dspn
R9C12	ENST
R9C14	ENSTcpx
R15C4:R20C4	Exc.
R15C1:R20C1	F
R15C1:R20C2	FCUM
R6C5:R6C10	Fe2O3
R12C12	FEM1
R12C14	FEM1cpx
R5C5:R5C10	FeO
R14C12	FM_2
R14C14	FM_2cpx
R2C5:R11C5	Form._Wt.
R15C3:R20C3	FRAC
R11C12	FS
R11C14	FScpx
R12C1	F_7
R13C1	F_9
R13C4	f_O2
R2C9:R11C9	G_1
R2C7:R11C7	G_1_i
R22C9:R31C9	G_1_ii
R2C8:R11C8	G_1_ratio
R2C6:R11C6	G_4
R22C8:R31C8	G_4_ii
R10C12	HEDEN

R13C8	SUM
R43C8:R43C15	Sums
R43C8	Sum_liquid
R43C9:R43C14	Sum_phases
R43C15	Sum_solid
R43C6	Sum_W_ARRAY
R13C6	Sys._mass
R4C1:R9C1	Temp.
R3C12	TER
R3C14	TERcpx
R23C13	TERspn
R22C1:R24C7	Ti
R3C5:R3C10	TiO2
R4C1	T_max
R4C1:R9C3	T_Phase_data
R11C3	VAL
R11C2	VAL_calc.
R33C1:R42C6	W_ARRAY
R33C1:R42C7	W_ARRAY_OUT
R32C1:R32C6	W_Array_phase
R2C3	XLFRAC
R13C7	Xlnf
R13C5	Xlnm
R21C2:R21C7	X_Array
R22C2:R31C7	X_Array_values
R4C2	X_Phase

Names with values.

R1C1	"423-3-02 fc"

Cells with formulas.

R2C1	Iteration+1
R2C2	EQ.MACRO!Loops
R2C3	EQ.INPUT!XLFRAC
R2C8	G_1_i SiO2
R2C10	G_1 SiO2/Xlnf
R2C12	IF(Loops=0,1400,IF(D>0,OPXTP-TER,OPXTP+TER))
R2C14	IF(Loops=0,1400,IF(Exc. Cp,0,IF(Dcpx>0,CPXTP-TERcpx,CPXTP+TERcpx)))
R3C8	G_1_i TiO2
R3C10	G_1 TiO2/Xlnm
R3C12	IF(AND(Loops=1,Iteration<=2),50,IF(AND(Loops>1,Iteration<=2),2,IF(OR(AND(D<0,B>0),AND(D>0,B<0)),RC/2,RC)))
R3C14	IF(AND(Loops=1,Iteration<=2),50,IF(AND(Loops>1,Iteration<=2),2,IF(OR(AND(Dcpx<0,Bcpx>0),AND(Dcpx>0,Bcpx<0)),RC/2,RC)))
R4C1	IF(Exc. Pl,0,PLTP)
R4C8	G_1_i Al2O3
R4C10	(G_1 Al2O3-G_1 Na2O-G_1 K2O)/Xlnm
R4C12	D
R4C14	Dcpx
R5C1	IF(Exc. Ol,0,OLTP)
R5C8	(G_1_i FeO+G_1_i Fe2O3)-G_1_ratio Fe2O3
R5C10	G_1 FeO/Xlnm
R5C12	EXP(30000/OPXTP-23.7)*(Melt_comp. Al2O3)
R5C14	EXP(23350/CPXTP-18.54)*(Melt_comp. Al2O3)
R6C1	IF(Exc. Cp,0,CPXTP)
R6C8	(G_1_i FeO+G_1_i Fe2O3)*EXP(0.5*RATIO)/(1+(EXP(0.5*RATIO)))
R6C10	G_1 Fe2O3/Xlnm
R6C12	EXP(10526/OPXTP-6.3)*(Melt_comp. Cr2O3)*VAL
R6C14	EXP(36000/CPXTP-24.7)*(Melt_comp. Cr2O3)*VAL
R7C1	IF(Exc. Sp,0,SPTP)
R7C8	G_1_i MgO
R7C10	G_1 MgO/Xlnm
R7C12	EXP(6250/OPXTP-6.25)*(Melt_comp. TiO2)
R7C14	EXP(4902/CPXTP-5.43)*(Melt_comp. TiO2)
R8C1	IF(Exc. Il,0,OXTP)
R8C8	G_1_i CaO
R8C10	G_1 CaO/Xlnm

R10C14	HEDENcpx
R20C1:R20C4	Il
R22C7:R31C7	Ilm
R33C6:R42C6	Ilmenite
R15C1:R20C2,R22C1:R31C9,R33C1:R42C6,R33C8:R42C15	INIT
R2C1	Iteration
R10C5:R10C10	K2O
R17C6	Liq._mass
R33C8:R42C8	Liquid
R2C2	Loops
R9C1	L_Phase
R22C10:R31C11	Mass_neg.
R2C10:R11C10	Melt_comp.
R15C12	MGM2
R15C14	MGM2cpx
R7C5:R7C10	MgO
R16C12	MM1
R16C14	MM1cpx
R9C5:R9C10	Na2O
R15C1:R15C4	Ol
R15C10	OLCA
R19C10	OLCR
R14C10	OLF
R20C10	OLFE
R33C1:R42C1	Olivine
R17C10	OLMG
R16C10	OLTI
R18C10	OLTP
R22C2:R31C2	Olv
R33C8:R42C8	OO
R16C1:R16C4	Op
R22C3:R31C3	Opx
R5C12	OPXAL
R19C12	OPXCA
R6C12	OPXCR
R18C12	OPXFE
R20C12	OPXMG
R7C12	OPXTI
R2C12	OPXTP
R33C2:R42C2	Orthopx.
R24C15	OXCR
R27C15	OXFE
R2C4:R11C4	Oxides
R33C8:R42C15	Oxide_Output
R23C15	OXMG
R22C15	OXTP
R4C2:R9C2	Phase
R4C3:R9C3	Phase_Index
R18C1:R18C4	Pl
R22C5:R31C5	Pla
R33C4:R42C4	Plagioclase
R19C8	PLCA
R15C8	PLNA
R18C8	PLTP
R13C3	RATIO
R2C5:R2C10	SiO2
R33C9:R42C14	Sol._array
R15C6	Sol._mass
R33C15:R42C15	Solid
R19C1:R19C4	Sp
R28C13	SPAL
R29C13	SPCR
R31C13	SPFE2
R27C13	SPFE3
R33C5:R42C5	Spinel
R25C13	SPMG
R22C6:R31C6	Spn
R26C13	SPTI
R22C13	SPTP
R22C1:R31C1	Sub._Phase

R13C8	SUM
R43C8:R43C15	Sums
R43C8	Sum_liquid
R43C9:R43C14	Sum_phases
R43C15	Sum_solid
R43C6	Sum_W_ARRAY
R13C6	Sys._mass
R4C1:R9C1	Temp.
R3C12	TER
R3C14	TERcpx
R23C13	TERspn
R22C1:R24C7	Ti
R3C5:R3C10	TiO2
R4C1	T_max
R4C1:R9C3	T_Phase_data
R11C3	VAL
R11C2	VAL_calc.
R33C1:R42C6	W_ARRAY
R33C1:R42C7	W_ARRAY_OUT
R32C1:R32C6	W_Array_phase
R2C3	XLFRAC
R13C7	Xlnf
R13C5	Xlnm
R21C2:R21C7	X_Array
R22C2:R31C7	X_Array_values
R4C2	X_Phase

Names with values.

R1C1	"423-3-02 fc"

Cells with formulas.

R2C1	Iteration+1
R2C2	EQ.MACRO!Loops
R2C3	EQ.INPUT!XLFRAC
R2C8	G_1_i SiO2
R2C10	G_1 SiO2/Xlnf
R2C12	IF(Loops=0,1400,IF(D>0,OPXTP-TER,OPXTP+TER))
R2C14	IF(Loops=0,1400,IF(Exc. Cp,0,IF(Dcpx>0,CPXTP-TERcpx,CPXTP+TERcpx)))
R3C8	G_1_i TiO2
R3C10	G_1 TiO2/Xlnm
R3C12	IF(AND(Loops=1,Iteration<=2),50,IF(AND(Loops>1,Iteration<=2),2,IF(OR(AND(D<0,B>0),AND(D>0,B<0)),RC/2,RC)))
R3C14	IF(AND(Loops=1,Iteration<=2),50,IF(AND(Loops>1,Iteration<=2),2,IF(OR(AND(Dcpx<0,Bcpx>0),AND(Dcpx>0,Bcpx<0)),RC/2,RC)))
R4C1	IF(Exc. Pl,0,PLTP)
R4C8	G_1_i Al2O3
R4C10	(G_1 Al2O3-G_1 Na2O-G_1 K2O)/Xlnm
R4C12	D
R4C14	Dcpx
R5C1	IF(Exc. Ol,0,OLTP)
R5C8	(G_1_i FeO+G_1_i Fe2O3)-G_1_ratio Fe2O3
R5C10	G_1 FeO/Xlnm
R5C12	EXP(30000/OPXTP-23.7)*(Melt_comp. Al2O3)
R5C14	EXP(23350/CPXTP-18.54)*(Melt_comp. Al2O3)
R6C1	IF(Exc. Cp,0,CPXTP)
R6C8	(G_1_i FeO+G_1_i Fe2O3)*EXP(0.5*RATIO)/(1+(EXP(0.5*RATIO)))
R6C10	G_1 Fe2O3/Xlnm
R6C12	EXP(10526/OPXTP-6.3)*(Melt_comp. Cr2O3)*VAL
R6C14	EXP(36000/CPXTP-24.7)*(Melt_comp. Cr2O3)*VAL
R7C1	IF(Exc. Sp,0,SPTP)
R7C8	G_1_i MgO
R7C10	G_1 MgO/Xlnm
R7C12	EXP(6250/OPXTP-6.25)*(Melt_comp. TiO2)
R7C14	EXP(4902/CPXTP-5.43)*(Melt_comp. TiO2)
R8C1	IF(Exc. Il,0,OXTP)
R8C8	G_1_i CaO
R8C10	G_1 CaO/Xlnm

R8C12	EXP(38500/OPXTP-25.6)*(Melt_comp. MgO)*(Melt_comp. CaO)*(Melt_comp. SiO2)^2
R8C14	EXP(11737/CPXTP-5.54)*Melt_comp. MgO*Melt_comp. CaO*Melt_comp. SiO2^2
R9C1	IF(Exc. Op,0,OPXTP)
R9C8	G_1_i Na2O
R9C10	G_1 Na2O/XInf
R9C12	EXP(7180/OPXTP-2.78)*(Melt_comp. MgO)^2*(Melt_comp. SiO2)^2
R9C14	EXP(22719/CPXTP-15.18)*Melt_comp. MgO^2*Melt_comp. SiO2^2
R10C8	G_1_i K2O
R10C10	G_1 K2O/XInf
R10C12	EXP(34448/OPXTP-24.86)*(Melt_comp. FeO)*(Melt_comp. CaO)*(Melt_comp. SiO2)^2
R10C14	EXP(8317/CPXTP-5.01)*Melt_comp. FeO*Melt_comp. CaO*Melt_comp. SiO2^2
R11C1	(Melt_comp. Al2O3)/(SUM(Melt_comp.))
R11C2	-50*(Melt_comp. FeO/(Melt_comp. FeO+Melt_comp. Fe2O3))+51
R11C3	IF(VAL_calc.>5,5,VAL_calc.)
R11C8	G_1_i Cr2O3
R11C10	G_1 Cr2O3/XInm
R11C12	EXP(10230/OPXTP-7.38)*(Melt_comp. FeO)^2*(Melt_comp. SiO2)^2
R11C14	EXP(12711/CPXTP-10.04)*Melt_comp. FeO^2*Melt_comp. SiO2^2
R12C1	EQ.MACRO!F_7
R12C12	1/(1+(DIOP/HEDEN))
R12C14	1/(1+(DIOPcpx/HEDENcpx))
R13C1	EQ.MACRO!F_9
R13C3	EQ.MACRO!ratio
R13C4	EQ.MACRO!f_O2
R13C5	G_1 TiO2+G_1 Al2O3+G_1 FeO+G_1 Fe2O3+G_1 MgO+G_1 CaO+G_1 Cr2O3-G_1 Na2O-G_1 K2O
R13C6	EQ.MACRO!Sys._mass
R13C7	G_1 SiO2+G_1 Na2O+G_1 K2O
R13C8	SUM(R[-11]C:R[-2]C)
R13C12	HEDEN/FEM1
R13C14	HEDENcpx/FEM1cpx
R14C10	(0.213*(Melt_comp. FeO/Melt_comp. MgO))/(1+0.322*(Melt_comp. FeO/Melt_comp. MgO))
R14C12	FS/FEM1
R14C14	FScpx/FEM1cpx
R15C6	EQ.MACRO!Sol._mass
R15C8	EXP(9031/PLTP-6.25)*Melt_comp. Na2O*Melt_comp. SiO2^3
R15C10	0.002
R15C12	ENST/(1-FEM1-OPXAL-OPXTI-OPXCR)
R15C14	ENSTcpx/(1-FEM1cpx-CPXAL-CPXTI-CPXCR)
R16C8	EXP(16667/PLTP-9.32)*Melt_comp. CaO*Melt_comp. Al2O3^2*Melt_comp. SiO2^2
R16C10	0.0178*Melt_comp. TiO2
R16C12	1-FEM1-OPXAL-OPXCR-OPXTI
R16C14	1-FEM1cpx-CPXAL-CPXCR-CPXTI
R17C6	EQ.MACRO!Liq._mass
R17C8	0.2-R[-1]C-R[-2]C
R17C10	(2/3)-OLCA-OLTI-OLCR-OLF
R17C12	IF(Iteration<=1,1,1-FM_2-CAM2-MGM2)
R17C14	IF(Iteration<=1,1,1-FM_2cpx-CAM2cpx-MGM2cpx)
R18C2	0.0625
R18C8	IF(Loops=0,1400,PLTP-500*Dpla)
R18C10	IF(Loops=0,1500,12481/(LN((OLF*OLMG)/(Melt_comp. FeO*Melt_comp. MgO))+8.091))
R18C12	(FEM1+FM_2)/2
R18C14	(FEM1cpx+FM_2cpx)/2
R19C6	Sol._mass/Sys._mass
R19C8	0.2-PLNA
R19C10	EXP(9242/OLTP-5.47)*(Melt_comp. Cr2O3)/VAL
R19C12	CAM2/2
R19C14	CAM2cpx/2
R20C10	(2/3)-OLCA-OLMG-OLTI-OLCR
R20C12	1-OPXAL-OPXCA-OPXCR-OPXFE-OPXTI
R20C14	1-CPXAL-CPXCA-CPXCR-CPXFE-CPXTI
R22C13	IF(Loops=0,1300,IF(Dspn>0,SPTP-TERspn,SPTP+TERspn))
R22C15	IF(Loops=0,1300,OXTP-100*Dilm)

R23C13
IF(AND(Loops=1,Iteration<=1),50,IF(AND(Loops>1,Iteration<=1),2,IF(OR(AND(Dspn<0,Bspn>0),AND(Dspn>0,Bspn<0)),RC/2,RC)))
R23C15 1.57*Melt_comp. MgO
R24C13 Dspn
R24C15 11*Melt_comp. Cr2O3
R25C13 Melt_comp. MgO*0.32/(Melt_comp. MgO+Melt_comp. FeO)
R25C15 EXP(8950/OXTP-3.3)*Melt_comp. FeO*Melt_comp. TiO2
R26C13 (EXP(25000/SPTP-17.8)*Melt_comp. TiO2*Melt_comp. MgO^2)/(SPMG^2)
R26C15 1-OXMG-OXCR-R[-1]C
R27C13 EXP(8802/SPTP-4.95)*Melt_comp. Fe2O3
R27C15 1-OXMG-OXCR
R28C13 EXP(-4000/SPTP+5.2)*G_1 Al2O3^2
R29C13 EXP(11261/SPTP-1.89)*Melt_comp. Cr2O3
R30C11 "Al2O3"
R30C13 IF(Iteration<=1,1,2/3-R[-2]C-SPFE3-SPCR-2*SPTI)
R31C13 1-SPMG-SPTI-SPFE3-SPAL-SPCR
R33C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R33C15 SUM(RC[-6]:RC[-1])
R34C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R34C15 SUM(RC[-6]:RC[-1])
R35C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R35C15 SUM(RC[-6]:RC[-1])
R36C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R36C15 SUM(RC[-6]:RC[-1])
R37C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R37C15 SUM(RC[-6]:RC[-1])
R38C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R38C15 SUM(RC[-6]:RC[-1])
R39C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R39C15 SUM(RC[-6]:RC[-1])
R40C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R40C15 SUM(RC[-6]:RC[-1])
R41C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R41C15 SUM(RC[-6]:RC[-1])
R42C7 SUM(R[+11]C[-6]:R[+11]C[-1])
R42C15 SUM(RC[-6]:RC[-1])
R43C6 IF(SUM(W_ARRAY)=0,1,SUM(W_ARRAY))
R43C8 SUM(R[-10]C:R[-1]C)
R43C9 SUM(R[-10]C:R[-1]C)
R43C10 SUM(R[-10]C:R[-1]C)
R43C11 SUM(R[-10]C:R[-1]C)
R43C12 SUM(R[-10]C:R[-1]C)
R43C13 SUM(R[-10]C:R[-1]C)
R43C14 SUM(R[-10]C:R[-1]C)
R43C15 SUM(R[-10]C:R[-1]C)

Values of cells.
R1C1 "Iteration"
R1C2 "Loops"
R1C3 "XLFRAC"
R1C4 "Oxides"
R1C5 "Form. Wt."
R1C6 "G 4"
R1C7 "G 1 i"
R1C8 "G 1 ratio"
R1C9 "G 1"
R1C10 "Melt comp."
R1C11 "ORTHOPYROXENE"
R1C13 "CLINOPYROXENE"
R2C1 22
R2C2 8
R2C3 0.00025
R2C4 60.09
R2C5 60.09
R2C6:R11C6
{0.48314760922719;;0.0056402815700535;;0.18126983352793;;0.06603
6069143479;;0.013271931972652;;0.074121463395936;;0.095929463220843;;0.
060835550939383;;0.017247797002537;;0}

R2C7:R11C7	{0.48314760922719;;0.0056402815700535;;0.18126983352793;;0.06603 6069143479;;0.013271931972652;;0.074121463395936;;0.095929463220843;;0. 060835550939383;;0.017247797002537;;0}
R2C8	0.48314760922719
R2C9	0.48435850549092
R2C10	0.8608712742152
R2C11	"OPXTP"
R2C12	1393.1353037357
R2C13	"CPXTP"
R2C14	1398.3993282318
R3C1	"Temp."
R3C2	"Phase"
R3C3	"Phase Index"
R3C4	79.9
R3C5	79.9
R3C6	0.0056402815700535
R3C7	0.0056402815700535
R3C8	0.0056402815700535
R3C9	0.0056544176140887
R3C10	0.015746808570347
R3C11	"TER"
R3C12	0.000030517578125
R3C13	"TERcpx"
R3C14	0.0001220703125
R4C1	1459.0867408987
R4C2	"PL"
R4C3	4
R4C4	101.94
R4C5	50.97
R4C6	0.18126983352793
R4C7	0.18126983352793
R4C8	0.18126983352793
R4C9	0.18172414388765
R4C10	0.28808097882858
R4C11	"B"
R4C12	-8.9776450329371E-08
R4C13	"Bcpx"
R4C14	-9.1397333788767E-07
R5C1	1421.0157323939
R5C2	"OL"
R5C3	1
R5C4	71.85
R5C5	71.85
R5C6	0.066036069143479
R5C7	0.066036069143479
R5C8	0.063036233873546
R5C9	0.063194219422101
R5C10	0.17598758066842
R5C11	"OPXAL"
R5C12	0.033029551826436
R5C13	"CPXAL"
R5C14	0.045645457758074
R6C1	1398.3993282318
R6C2	"CP"
R6C3	3
R6C4	159.7
R6C5	79.85
R6C6	0.013271931972652
R6C7	0.013271931972652
R6C8	0.016271767242585
R6C9	0.01631254861412
R6C10	0.045428300110167
R6C11	"OPXCR"
R6C13	"CPXCR"
R7C1	1300.0002679825
R7C2	"SP"
R7C3	5
R7C4	40.32
R7C5	40.32

R7C6	0.074121463395936
R7C7	0.074121463395936
R7C8	0.074121463395936
R7C9	0.074307231474622
R7C10	0.20693585604783
R7C11	"OPXTI"
R7C12	0.0026991077815012
R7C13	"CPXTI"
R7C14	0.0022980804346729
R8C1	1022.9635568177
R8C2	"IL"
R8C3	6
R8C4	56.08
R8C5	56.08
R8C6	0.095929463220843
R8C7	0.095929463220843
R8C8	0.095929463220843
R8C9	0.096169887940694
R8C10	0.26782047577466
R8C11	"DIOP"
R8C12	0.31445990531311
R8C13	"DIOPcpx"
R8C14	0.71231308655815
R9C2	"OP"
R9C3	2
R9C4	61.98
R9C5	30.991
R9C6	0.060835550939383
R9C7	0.060835550939383
R9C8	0.060835550939383
R9C9	0.060988020991862
R9C10	0.10839664163617
R9C11	"ENST"
R9C12	0.34079612432062
R9C13	"ENSTcpx"
R9C14	0.09219207447779
R10C1	"ALUM"
R10C2	"VAL calc."
R10C3	"VAL"
R10C4	94.2
R10C5	47.1
R10C6	0.017247797002537
R10C7	0.017247797002537
R10C8	0.017247797002537
R10C9	0.017291024563947
R10C10	0.03073208414863
R10C11	"HEDEN"
R10C12	0.030579008751715
R10C13	"HEDENcpx"
R10C14	0.089198903899872
R11C1	0.14404048941429
R11C2	11.258591197348
R11C3	5
R11C4	152.02
R11C5	76.01
R11C11	"FS"
R11C12	0.022122604426803
R11C13	"FScpx"
R11C14	0.0088740321053195
R12C1	0.025
R12C2	"F_7"
R12C3	"RATIO"
R12C4	"f_O2"
R12C5	"Xlnm"
R12C6	"Sys. mass"
R12C7	"Xlnf"
R12C8	"SUM"
R12C11	"FEM1"
R12C12	0.088624811594352
R12C13	"FEM1cpx"

R12C14	0.11128829632218
R13C1	0.15
R13C2	"F_9"
R13C3	-2.7085563337501
R13C4	-7.9393288093445
R13C5	0.35908340339747
R13C6	6559.7908139126
R13C7	0.56263755104672
R13C8	0.9975
R13C9	"OLIVINE"
R13C11	"CAM2"
R13C12	0.34503891406483
R13C13	"CAM2cpx"
R13C14	0.80151199045802
R14C1	"F"
R14C2	"CUM"
R14C3	"FRAC"
R14C4	"Exc."
R14C5	"Phase"
R14C6	"Sol. mass"
R14C7	"PLAGIOCLASE"
R14C9	"OLF"
R14C10	0.14220336191475
R14C11	"FM 2"
R14C12	0.24962089090876
R14C13	"FM 2cpx"
R14C14	0.079739131594118
R15C4	FALSE
R15C5	"Ol"
R15C6	53.93622410044
R15C7	"PLNA"
R15C8	0.065095427896386
R15C9	"OLCA"
R15C10	0.002
R15C11	"MGM2"
R15C12	0.38919371357361
R15C13	"MGM2cpx"
R15C14	0.10965219457923
R16C4	TRUE
R16C5	"Op"
R16C6	"Liq. mass"
R16C7	"PLCA"
R16C8	0.13490457210358
R16C9	"OLTI"
R16C10	0.00028029319255218
R16C11	"MM1"
R16C12	0.87564652879771
R16C13	"MM1cpx"
R16C14	0.84076816548507
R17C4	FALSE
R17C5	"Cp"
R17C6	6842.021132594
R17C7	"Dpla"
R17C8	3.7803093988487E-14
R17C9	"OLMG"
R17C10	0.52218301155937
R17C11	"D"
R17C12	0.016146481452805
R17C13	"Dcpx"
R17C14	0.009096683368635
R18C2	0.0625
R18C4	FALSE
R18C5	"Pl"
R18C6	"Crystalised"
R18C7	"PLTP"
R18C8	1459.0867408986
R18C9	"OLTP"
R18C10	1417.7389946808
R18C11	"OPXFE"
R18C12	0.16912285125156

R18C13	"CPXFE"
R18C14	0.095513713958149
R19C4	FALSE
R19C5	"Sp"
R19C6	0.0082222475732072
R19C7	"PLCA"
R19C8	0.13490457210361
R19C9	"OLCR"
R19C11	"OPXCA"
R19C12	0.17251945703241
R19C13	"CPXCA"
R19C14	0.40075599522901
R20C4	FALSE
R20C5	"Il"
R20C9	"OLFE"
R20C10	0.14220336191475
R20C11	"OPXMG"
R20C12	0.62262903210809
R20C13	"CPXMG"
R20C14	0.45578675262009
R21C1	"Sub. Phase"
R21C2	"Olv"
R21C3	"Opx"
R21C4	"Cpx"
R21C5	"Pla"
R21C6	"Spn"
R21C7	"Ilm"
R21C8	"G 4 ii"
R21C9	"G 1 ii"
R21C10	"Mass"
R21C11	"negative"
R21C12	"SPINEL"
R21C14	"ILMENITE"
R22C1:R31C1	{0.46488971247623;;0;;0.33511028752377;;0;;0;;0;;0.13511028752377;;0.064889712476233;;0;;0}
R22C5:R31C5	{0;;0;;0;;0;;0;;0;;0;;0;;0;;0;;0}
R22C8:R31C8	{0.48314760922719;;0.0056402815700535;;0.18126983352793;;0.066036069143479;;0.013271931972652;;0.074121463395936;;0.095929463220843;;0.060835550939383;;0.017247797002537;;0}
R22C9:R31C9	{0.48314760922719;;0.0056402815700535;;0.18126983352793;;0.066036069143479;;0.013271931972652;;0.074121463395936;;0.095929463220843;;0.060835550939383;;0.017247797002537;;0}
R22C11	"SiO2"
R22C12	"SPTP"
R22C13	1300.0002684593
R22C14	"OXTP"
R22C15	1022.9635568242
R23C8	0.0056402815700535
R23C9	0.0056402815700535
R23C11	"TiO2"
R23C12	"TERspn"
R23C13	4.7683715820312E-07
R23C14	"OXMG"
R23C15	0.32488929399509
R24C1	0.33511028752377
R24C8	0.18126983352793
R24C9	0.18126983352793
R24C11	"Al2O3"
R24C12	"Bspn"
R24C13	-0.035099500917332
R24C14	"OXCR"
R25C8	0.066036069143479
R25C9	0.066036069143479
R25C11	"FeO"
R25C12	"SPMG"
R25C13	0.17293136848235
R25C14	"OXFE"

R25C15	0.6444425265506
R26C8	0.013271931972652
R26C9	0.013271931972652
R26C11	"Na2O"
R26C12	"SPTI"
R26C13	0.094295277825133
R26C14	"Dilm"
R26C15	0.030668179454314
R27C8	0.074121463395936
R27C9	0.074121463395936
R27C11	"CaO"
R27C12	"SPFE3"
R27C13	0.28059240318841
R27C14	"OXFE"
R27C15	0.67511070600491
R28C1	0.13511028752377
R28C8	0.095929463220843
R28C9	0.095929463220843
R28C11	"MgO"
R28C12	"SPAL"
R28C13	0.27597270562278
R29C1	0.064889712476233
R29C8	0.060835550939383
R29C9	0.060835550939383
R29C11	"Fe2O3"
R29C12	"SPCR"
R30C8	0.017247797002537
R30C9	0.017247797002537
R30C11	"Al2O3"
R30C12	"Dspn"
R30C13	-0.078488997794787
R31C11	"Cr2O3"
R31C12	"SPFE2"
R31C13	0.17620824488133
R32C1	"Olivine"
R32C2	"Orthopx."
R32C3	"Clinopx."
R32C4	"Plagioclase"
R32C5	"Spinel"
R32C6	"Ilmenite"
R32C7	"Solid"
R32C8	"Oxide Output"
R32C9	"Olivine"
R32C10	"Orthopx."
R32C11	"Clinopx."
R32C12	"Plagioclase"
R32C13	"Spinel"
R32C14	"Ilmenite"
R32C15	"Solid"
R33C4:R42C4	{0.46488971247623;;0;;0.33511028752377;;0;;0;;0;;0.13511028752377;;0.064889712476233;;0;;0}
R33C7	0.1937040468651
R33C8:R42C8	{29.032339838462;;0.45065849744727;;9.2393234149186;;4.744691567959;;1.0597637680163;;2.9885774041241;;5.3797242974249;;1.8853545591624;;0.81237123881949;;0}
R33C9:R42C9	{0;;0;;0;;0;;0;;0;;0;;0;;0;;0}
R33C10:R42C10	{0;;0;;0;;0;;0;;0;;0;;0;;0;;0}
R33C11:R42C11	{0;;0;;0;;0;;0;;0;;0;;0;;0;;0}
R33C12:R42C12	{34.830586623808;;0;;21.296637723044;;0;;0;;0;;9.4472426953347;;2.5073796052075;;0;;0}
R33C13:R42C13	{0;;0;;0;;0;;0;;0;;0;;0;;0;;0}
R33C14:R42C14	{0;;0;;0;;0;;0;;0;;0;;0;;0;;0}
R33C15	34.830586623808
R34C8	0.45065849744727
R35C4	0.33511028752377
R35C7	0.13962928646824
R35C8	9.2393234149186

R35C12	21.296637723044
R35C15	21.296637723044
R36C8	4.744691567959
R37C8	1.0597637680163
R38C8	2.9885774041241
R39C4	0.13511028752377
R39C7	0.056295953134904
R39C8	5.3797242974249
R39C12	9.4472426953347
R39C15	9.4472426953347
R40C4	0.064889712476233
R40C7	0.02703738019843
R40C8	1.8853545591624
R40C12	2.5073796052075
R40C15	2.5073796052075
R41C8	0.81237123881949
R43C1	"Total solid comp (W_Array*CUM)"
R43C5	"Sum_W_ARRAY"
R43C6	1
R43C7	"Sums"
R43C8	55.592804586334
R43C12	68.081846647394
R43C15	68.081846647394
R44C4	0.1937040468651
R46C4	0.13962928646824
R50C4	0.056295953134904
R51C4	0.02703738019843

Cross reference of Excel file EQ.MACRO

Names with cell references

R54C1	Again
R86C3	Beeper
R29C3:R38C3	CP
R80C3	END
R1C1	EQUIL
R2C3:R77C3	Formulas
R88C2	Help
R71C2	Init.ratio
R89C1	Merror
R3C3:R12C3	OL
R16C3:R25C3	OP
R5C2	Output
R68C3:R77C3	OX
R93C3	Perror
R42C3:R51C3	PL
R82C2	Ratio_fO2
R51C2	Recalc.
R55C3:R64C3	SP

Names with values.

0	ADD
-33.750258263241	Cryst.
-1.3614368268421	Cr_ratio
0	CUM
FALSE	error
0.05	F
0.025	F_7
0.15	F_9
-7.9393288093445	f_O2

EQ.SCRATCH!R2C9:R11C9 G_1
{0.43797520489887;;0.0059992534976616;;0.15575541254152;;0.059827969441957;;0.01579321317871;;0.023807941310019;;0.14449050361295;;0.022549558906951;;0.0088009426113542;;0}G_1_i
{0.43800374865421;;0.0068103604920225;;0.15839804388455;;0.062852279975251;;0.017731812534068;;-0.0141450516597;;0.14587315538867;;0.02441743060366;;0.010058220127262;;0} G_1_ii

{0.4898950127745;;0.0060451827172524;;0.16598308920187;;0.065668085641972;;0.01579321317871;;0.0
65162068752598;;0.15936888713653;;0.023283517985216;;0.00880094261135
42;;0} G_4
{0.500543091313;;0.0068562897116133;;0.17800618576174;;0.068692396175267;;0.017731812534068;;0.0
27209075782879;;0.16513200412909;;0.025770924465087;;0.01005822012726
2;;0} G_4_ii
20 i
6842.021132594 Liq._mass
8 Loops
{0;;0;;0;;0;;0;;0;;0;;0;;0;;0;;0} OO
TRUE OUTFILE
-2.7085563337501 ratio
EQ.INPUT!R17C6 report
53.93622410044 Sol._mass
FALSE Start
{0.42706987722853;;0;;0.37293012277147;;0;;0;;0;;0.17293012277147;;0.027069877228535;;0;;0}
Sub._Phase
6559.7908139126 Sys._mass
0 Terminate
{2.124847083643,0,1.8724927250642,0,0,0;;0.0014879820180702,0,0.0037526211104571,0,0,0;;0,0,0.06229
270416375,0,0,0;;0.58451342965456,0,0.16253470779527,0,0,0;;0,0,0,0,0,0;;2.5
14200894857,0,0.6246459151228,0,0,0;;0.011898295002566,0,0.749
Total_solid
{0.42706987722853;;0;;0.37293012277147;;0;;0;;0;;0.17293012277147;;0.027069877228535;;0;;0}
W_Phase
{0.021353493861427;;0;;0.018646506138574;;0;;0;;0;;0.008646506138574;;0.0013534938614268;;0;;0}
X_Phase

Cells with formulas.

R2C2	FORMULA.ARRAY(GET.NAME("OO"))
R3C1	IF(DOCUMENTS()="EQ.INPUT",GOTO(R[+8]C))
R3C2	SELECT(OFFSET(SELECTION(),0,1))
R3C3	1/3
R4C1	OPEN("EQ.INPUT")
R4C2	RETURN()
R4C3	EQ.SCRATCH!OLTI
R5C1	SELECT(EQ.INPUT!Input,EQ.INPUT!Id.)
R6C1	ALERT("Do you want help?",1)
R6C2	SELECT(!OO)
R6C3	EQ.SCRATCH!OLFE
R7C1	IF(R[-1]C,GOTO(Help))
R8C1	BEEP()
R8C2	R[-6]C()
R8C3	EQ.SCRATCH!OLMG
R9C1	MESSAGE(TRUE,"Enter values in the input worksheet. Restart when done.")
R9C3	0.002
R10C1	HALT()
R10C2	R[-8]C()
R12C1	MESSAGE(TRUE,"Opening and initialising worksheets...")
R12C2	R[-10]C()
R12C3	EQ.SCRATCH!OLCR
R13C1	ALERT("Screen echo: OK=on, Cancel=off.",1)
R14C1	INPUT("Save to other than default volume/directory? Enter path:",2,"Volume:directory path")
R14C2	R[-12]C()
R14C3	RETURN()
R15C1	IF(R[-1]C=FALSE,SET.VALUE(R[+1]C,EQ.INPUT!Id.),SET.VALUE(R[+1]C,DEREF(R[-1]C)&":"&DEREF(EQ.INPUT!Id.)))
R16C2	R[-14]C()
R16C3	0.5-EQ.SCRATCH!OPXAL/2
R17C1	CALCULATION(3,TRUE,1,0)
R17C3	EQ.SCRATCH!OPXTI/2
R18C1	ECHO(R[-5]C)
R18C2	R[-16]C()
R18C3	EQ.SCRATCH!OPXAL
R19C1	SET.NAME("Start",TRUE)
R19C3	EQ.SCRATCH!OPXFE/2
R20C1	SET.NAME("Loops",0)

```
R20C2    R[-18]C()
R21C1    SET.NAME("F_7",0)
R21C2    FORMULA.FILL("=SUM(RC[-6]:RC[-1])")
R21C3    EQ.SCRATCH!OPXMG/2
R22C1    SET.NAME("F_9",0)
R22C2    FORMULA.GOTO("Sums")
R22C3    EQ.SCRATCH!OPXCA/2
R23C1    SET.NAME("error",FALSE)
R23C2    FORMULA.FILL("=SUM(R[-10]C:R[-1]C)")
R24C1    SET.NAME("OUTFILE",FALSE)
R25C1    SET.NAME("report",EQ.INPUT!Report)
R25C3    EQ.SCRATCH!OPXCR/2
R26C1    SET.NAME("Total_solid",0)
R27C1    SET.NAME("Terminate",0)
R27C2    IF(NOT(OUTFILE),SET.NAME("Sys._mass",Liq._mass),GOTO(R[+1]C))
R27C3    RETURN()
R28C1    SET.NAME("Sol._mass",0)
R28C2    ACTIVATE("EQ.OUTPUT.ROW")
R29C1    OPEN("EQ.SCRATCH")
R29C2    CALCULATION(3,TRUE,1,0)
R29C3    0.5-EQ.SCRATCH!CPXAL/2
R30C1    OPEN("EQ.OUTPUT.ROW")
R30C2    CALCULATE.NOW()
R30C3    EQ.SCRATCH!CPXTI/2
R31C1    NEW(1)
R31C2    FORMULA.GOTO(IF(OUTFILE,!OUTPUT,!ALL))
R31C3    EQ.SCRATCH!CPXAL
R32C1    DISPLAY(FALSE,FALSE,FALSE)
R32C2    COPY()
R32C3    EQ.SCRATCH!CPXFE/2
R33C1    FONT("Geneva",9)
R33C2    OPEN(DEREF(R[-17]C[-1]),FALSE)
R34C1    SAVE.AS(R[-18]C,1)
R34C2    PASTE.SPECIAL(4,1)
R34C3    EQ.SCRATCH!CPXMG/2
R35C1    CLOSE()
R35C2    ECHO(TRUE)
R35C3    EQ.SCRATCH!CPXCA/2
R36C1    ACTIVATE("EQ.SCRATCH")
R36C2    PASTE.SPECIAL(3,1)
R37C1    SELECT(EQ.SCRATCH!INIT)
R37C2    ECHO(R[-24]C[-1])
R38C1    FORMULA.FILL("=0")
R38C2    SELECT(ACTIVE.CELL())
R38C3    EQ.SCRATCH!CPXCR/2
R39C1    SELECT(!Iteration)
R39C2    SELECT(OFFSET(SELECTION(),IF(OUTFILE,8,10),0))
R40C1    FORMULA(GET.FORMULA(!Iteration))
R40C2    SET.NAME("OUTFILE",TRUE)
R40C3    RETURN()
R41C2    SAVE()
R42C2    CLOSE()
R42C3    0.4+EQ.SCRATCH!PLNA
R43C2    ACTIVATE("EQ.SCRATCH")
R44C1    SELECT(EQ.SCRATCH!G_4)
R44C2    SET.NAME("F_7",0)
R44C3    0.4-EQ.SCRATCH!PLNA
R45C1    FORMULA.ARRAY(GET.NAME("G_4"))
R45C2    SELECT(EQ.SCRATCH!F)
R46C2    FORMULA("=0")
R47C2    IF(ABS(Sysmass-Liq._mass)=1,SET.NAME("Terminate",1),)
R48C2    IF(EQ.SCRATCH!T_max<EQ.INPUT!Solidus_T+273,SET.NAME("Terminate",2))
R48C3    EQ.SCRATCH!PLCA
R49C1    SELECT(EQ.SCRATCH!G_1_i)
R49C2    IF(Terminate>0,GOTO(END),GOTO(Again))
R49C3    EQ.SCRATCH!PLNA
R50C1    FORMULA.ARRAY(GET.NAME("G_1_i"))
R51C1    Ratio_fO2()
R52C1    CALCULATE.NOW()
R53C3    RETURN()
```

```
R54C2    SELECT(!G_4_ii)
R55C1    ECHO(TRUE)
R55C2    FORMULA.ARRAY(GET.NAME("G_4_ii"))
R56C1    MESSAGE(TRUE,"Calculating equilibrium crystallisation temperatures of the
         phases...")
R56C3    EQ.SCRATCH!SPTI
R57C1    ECHO(R[-44]C)
R57C2    SELECT(!G_1_ii)
R57C3    EQ.SCRATCH!SPAL
R58C1    CALCULATION(3,TRUE,IF(Loops=0,30,20),0)
R58C2    FORMULA.ARRAY(GET.NAME("G_1_ii"))
R58C3    EQ.SCRATCH!SPFE2
R59C1    SET.NAME("Loops",Loops+1)
R59C2    IF(MIN(G_1_ii)<0,GOTO(Merror),)
R59C3    EQ.SCRATCH!SPFE3
R60C1    SELECT(!Iteration)
R60C3    EQ.SCRATCH!SPMG
R61C1    FORMULA(GET.FORMULA(!Iteration))
R61C2    SELECT(EQ.SCRATCH!G_4)
R62C1    CALCULATE.NOW()
R62C2    FORMULA.ARRAY(GET.NAME("G_4"))
R63C1    ECHO(TRUE)
R64C1    MESSAGE(TRUE,"Determining crystallising phases and new liquid
         composition...")
R64C2    SELECT(EQ.SCRATCH!G_1_i)
R64C3    EQ.SCRATCH!SPCR
R65C1    ECHO(R[-52]C)
R65C2    FORMULA.ARRAY(GET.NAME("G_1_i"))
R66C1    ACTIVATE("EQ.SCRATCH")
R66C2    Ratio_fO2()
R66C3    RETURN()
R67C1    SELECT(!T_Phase_data)
R67C2
             SET.NAME("F_7",EQ.SCRATCH!F_7+EQ.SCRATCH!XLFRAC*IF(EQ.SC
         RATCH!X_Phase="SP",0.1,IF(EQ.SCRATCH!X_Phase="IL",0.5,1)))
R68C1    SORT(1,!Temp.,2)
R68C2
             SET.NAME("F_9",EQ.SCRATCH!F_9+EQ.SCRATCH!XLFRAC*IF(EQ.SC
         RATCH!X_Phase="SP",0.1,IF(EQ.SCRATCH!X_Phase="IL",0.5,1)))
R69C1    IF(EQ.SCRATCH!L_Phase<0,GOTO(Perror))
R69C2    IF(OR(F_7>=report,Loops=2),GOTO(Output),GOTO(Again))
R69C3    0.5
R70C1    IF(Start,GOTO(Init.ratio))
R71C1
             FORMULA.GOTO(INDEX(EQ.SCRATCH!F,INDEX(EQ.SCRATCH!Phase_
         Index,1)))
R71C3    EQ.SCRATCH!OXFE/2
R72C1    SET.NAME("F",DEREF(SELECTION())+EQ.SCRATCH!XLFRAC*(1-
         INDEX(EQ.SCRATCH!FRAC,INDEX(EQ.SCRATCH!Phase_Index,1))))
R72C2    SET.NAME("Start",FALSE)
R73C1    FORMULA(GET.NAME("F"))
R73C2    Ratio_fO2()
R73C3    EQ.SCRATCH!OXMG/2
R74C1
             FORMULA.GOTO(INDEX(EQ.SCRATCH!CUM,INDEX(EQ.SCRATCH!Pha
         se_Index,1)))
R74C2    CALCULATION(3,TRUE,1,0)
R75C1
             SET.NAME("CUM",DEREF(SELECTION())+EQ.SCRATCH!XLFRAC*INDE
         X(EQ.SCRATCH!FRAC,INDEX(EQ.SCRATCH!Phase_Index,1)))
R75C2    CALCULATE.NOW()
R76C1    FORMULA(GET.NAME("CUM"))
R77C1    EQ.SCRATCH!X_Phase
R77C2    FORMULA.GOTO("G_1_ii")
R77C3    EQ.SCRATCH!OXCR
R78C1    IF(R[-1]C="OL",OL(),IF(R[-1]C="OP",OP(),IF(R[-1]C="CP",CP(),IF(R[-
         1]C="PL",PL(),IF(R[-1]C="SP",SP(),IF(R[-1]C="IL",OX()))))))
R78C2    FORMULA.ARRAY(GET.NAME("G_1_ii"))
R79C1    FORMULA.GOTO(EQ.SCRATCH!Sub._Phase)
R79C2    SET.NAME("Start",FALSE)
```

```
R79C3          RETURN()
R80C1          FORMULA.ARRAY(GET.NAME("Sub._Phase"))
R80C2          GOTO(Output)
R81C1
                    FORMULA.GOTO(DEREF(INDEX(EQ.SCRATCH!X_Array,INDEX(EQ.SC
               RATCH!Phase_Index,1))))
R81C3          Beeper()
R82C3          ALERT("Solidus reached on basis of "&IF(Terminate=1,"mass","T")&";; program
               terminated! Time "&HOUR(NOW())&":"&MINUTE(NOW()),3)
R83C1          FORMULA.ARRAY(GET.NAME("X_Phase"))
R83C2          SET.NAME("f_O2",-
               26738/IF(Start,1573,EQ.SCRATCH!T_max)+9.89+EQ.INPUT!f_O2)
R83C3          MESSAGE(FALSE)
R84C1
                    FORMULA.GOTO(DEREF(INDEX(EQ.SCRATCH!W_Array_phase,INDEX(
               EQ.SCRATCH!Phase_Index,1))))
R84C2
                    SET.NAME("ratio",0.21813*LN(10^f_O2)+13184.7/IF(Start,1573,EQ.SCRA
               TCH!T_max)-4.49933-2.15036*INDEX(EQ.SCRATCH!G_1_i,1)-
               8.35163*(INDEX(EQ.SCRATCH!G_1_i,3)+INDEX(EQ.SCRATCH!G_1_i,4))-
               4.49508*INDEX(EQ.SCRATCH!G_1_i,4))
R84C3          HALT()
R85C2          SET.NAME("ratio",ratio-
               5.43639*INDEX(EQ.SCRATCH!G_1_i,6)+0.073113*INDEX(EQ.SCRATCH!G_1_i,
               7)+3.54148*INDEX(EQ.SCRATCH!G_1_i,8)+4.18688*INDEX(EQ.SCRATCH!G_1
               _i,9))
R86C1          FORMULA.ARRAY(GET.NAME("W_Phase"))
R86C2          RETURN()
R87C1          GOTO(Recalc.)
R87C3          SET.NAME("i",0)
R88C3          IF(i<20,BEEP(),GOTO(R[+3]C))
R89C2          ALERT("Real Mac users don't need help!!",2)
R89C3          SET.NAME("i",i+1)
R90C1          FORMULA.GOTO(EQ.SCRATCH!G_1_ii)
R90C2          CLOSE()
R90C3          GOTO(R[-2]C)
R91C1          COPY()
R91C2          OPEN("EQ.HELP")
R91C3          RETURN()
R92C1          SELECT(OFFSET(SELECTION(),0,1))
R92C2          ALERT("When finished, close this window and start again.",2)
R93C1          PASTE.SPECIAL(3,1)
R93C2          HALT()
R94C1          FORMULA.GOTO(EQ.SCRATCH!Mass_neg.)
R94C3          Beeper()
R95C1          SORT(1,EQ.SCRATCH!Mass_neg.,1)
R95C3          ALERT("The temperature of
               "&DEREF(INDEX(EQ.SCRATCH!W_Array_phase,INDEX(EQ.SCRATCH!Phase_I
               ndex,6)))&" has gone negative! Time "&HOUR(NOW())&":"&MINUTE(NOW()),3)
R96C1          SELECT(OFFSET(ACTIVE.CELL(),0,1))
R96C3          GOTO(R[-13]C)
R97C1          Beeper()
R98C1          ALERT("The mass of "&DEREF(ACTIVE.CELL())&" has gone negative!      Time
               "&HOUR(NOW())&":"&MINUTE(NOW()),3)
R99C1          GOTO(R[-16]C[+2])

Values of cells.
R1C1           "EQUIL"
R1C2           "Output routine"
R1C3           "Stoichiometric formulas"
R2C1           "Opening procedure."
R2C2           TRUE
R2C3           "OL"
R3C1           TRUE
R3C2           TRUE
R3C3           0.33333333333333
R4C1           TRUE
R4C2           TRUE
R4C3           0.00017947966746561
R5C1           TRUE
```

R5C2	"Output"
R6C1	FALSE
R6C2	TRUE
R6C3	0.081203358094279
R7C1	FALSE
R7C2	TRUE
R8C1	TRUE
R8C2	#N/A
R8C3	0.58328382890492
R9C1	TRUE
R9C2	TRUE
R9C3	0.002
R10C1	TRUE
R10C2	#N/A
R11C1	"Initialise values and open worksheets"
R11C2	TRUE
R12C1	TRUE
R12C2	#N/A
R13C1	FALSE
R13C2	TRUE
R13C3	TRUE
R14C1	FALSE
R14C2	#N/A
R14C3	TRUE
R15C1	TRUE
R15C2	TRUE
R15C3	"OP"
R16C1	"test"
R16C2	#N/A
R16C3	0.49995050524282
R17C1	TRUE
R17C2	TRUE
R17C3	0.00018013364268801
R18C1	TRUE
R18C2	#N/A
R18C3	0.000098989514362042
R19C1	TRUE
R19C2	TRUE
R19C3	0.024675295351452
R20C1	TRUE
R20C2	#N/A
R21C1	TRUE
R21C2	TRUE
R21C3	0.47285087071347
R22C1	TRUE
R22C2	TRUE
R22C3	0.00027683885747127
R23C1	TRUE
R23C2	TRUE
R24C1	TRUE
R24C2	TRUE
R25C1	TRUE
R25C2	TRUE
R25C3	0.0019673666777391
R26C1	TRUE
R26C2	TRUE
R26C3	FALSE
R27C1	TRUE
R27C2	TRUE
R27C3	TRUE
R28C1	TRUE
R28C2	TRUE
R28C3	"CP"
R29C1	TRUE
R29C2	TRUE
R29C3	0.49038364261388
R30C1	TRUE
R30C2	TRUE
R30C3	0.0007391047243504
R31C1	TRUE

R31C2	TRUE
R31C3	0.01923271477223
R32C1	TRUE
R32C2	TRUE
R32C3	0.035598965906027
R33C1	TRUE
R33C2	TRUE
R34C1	TRUE
R34C2	TRUE
R34C3	0.24379871994665
R35C1	TRUE
R35C2	TRUE
R35C3	0.21024685203686
R36C1	TRUE
R36C2	TRUE
R37C1	TRUE
R37C2	TRUE
R38C1	TRUE
R38C2	TRUE
R39C1	TRUE
R39C2	TRUE
R39C3	TRUE
R40C1	TRUE
R40C2	TRUE
R40C3	TRUE
R41C1	"Compute melt components and initial iron ratio"
R41C2	TRUE
R41C3	"PL"
R42C1	TRUE
R42C2	TRUE
R42C3	0.42706987722853
R43C1	TRUE
R43C2	TRUE
R44C1	TRUE
R44C2	TRUE
R44C3	0.37293012277147
R45C1	TRUE
R45C2	TRUE
R46C1	TRUE
R46C2	TRUE
R47C1	TRUE
R47C2	#NAME?
R48C1	TRUE
R48C2	FALSE
R48C3	0.17293012277147
R49C1	TRUE
R49C2	TRUE
R49C3	0.027069877228535
R50C1	TRUE
R50C2	"Shift liquid composition, compute solid composition."
R51C1	#N/A
R51C2	"Recalc."
R52C1	TRUE
R52C2	TRUE
R52C3	TRUE
R53C1	"Begin iteration on T for phase compositions, compute compositions."
R53C2	TRUE
R53C3	TRUE
R54C1	"Again"
R54C2	TRUE
R54C3	"SP"
R55C1	TRUE
R55C2	TRUE
R56C1	TRUE
R56C2	TRUE
R56C3	0.0027537740729467
R57C1	TRUE
R57C2	TRUE
R57C3	0.26404451893592
R58C1	TRUE

R58C2	TRUE
R58C3	0.087530701706267
R59C1	TRUE
R59C2	TRUE
R59C3	0.092756043041687
R60C1	TRUE
R60C2	TRUE
R60C3	0.24855637321868
R61C1	TRUE
R61C2	TRUE
R62C1	TRUE
R62C2	TRUE
R63C1	TRUE
R63C2	TRUE
R64C1	TRUE
R64C2	TRUE
R64C3	0.3043585890245
R65C1	TRUE
R65C2	TRUE
R65C3	FALSE
R66C1	TRUE
R66C2	#N/A
R66C3	TRUE
R67C1	TRUE
R67C2	TRUE
R67C3	"OX"
R68C1	TRUE
R68C2	TRUE
R69C1	FALSE
R69C2	TRUE
R69C3	0.5
R70C1	FALSE
R70C2	"Compute initial iron ratio from given fO2"
R71C1	TRUE
R71C2	"Init.ratio"
R71C3	0.25727904450458
R72C1	TRUE
R72C2	TRUE
R73C1	TRUE
R73C2	#N/A
R73C3	0.24272095549542
R74C1	TRUE
R74C2	TRUE
R75C1	TRUE
R75C2	TRUE
R76C1	TRUE
R76C2	TRUE
R77C1	"PL"
R77C2	TRUE
R78C1	#N/A
R78C2	TRUE
R78C3	FALSE
R79C1	TRUE
R79C2	TRUE
R79C3	TRUE
R80C1	TRUE
R80C2	TRUE
R80C3	"END"
R81C1	TRUE
R81C2	"Compute iron ratio from given fO2"
R81C3	#N/A
R82C1	TRUE
R82C2	"Ratio_fO2"
R82C3	TRUE
R83C1	TRUE
R83C2	TRUE
R83C3	TRUE
R84C1	TRUE
R84C2	TRUE
R84C3	TRUE

R85C1	TRUE
R85C2	TRUE
R85C3	"Error handler: audible alert."
R86C1	TRUE
R86C2	TRUE
R86C3	"Beeper"
R87C1	TRUE
R87C2	"Help routine."
R87C3	TRUE
R88C1	"Error handler: negative mass."
R88C2	"Help"
R88C3	TRUE
R89C1	"Merror"
R89C2	TRUE
R89C3	TRUE
R90C1	TRUE
R90C2	TRUE
R90C3	TRUE
R91C1	TRUE
R91C2	TRUE
R91C3	TRUE
R92C1	TRUE
R92C2	TRUE
R92C3	"Error handler: negative temperature."
R93C1	TRUE
R93C2	TRUE
R93C3	"Perror"
R94C1	TRUE
R94C3	FALSE
R95C1	TRUE
R95C3	TRUE
R96C1	TRUE
R96C3	FALSE
R97C1	#N/A
R98C1	TRUE
R99C1	TRUE

Cross reference of Excel file EQ.OUTPUT.ROW

Names with cell references

R1C1:R10C24	ALL
R3C1:R10C24	OUTPUT

Names with values.

R1C1	"EQUIL"

Cells with formulas.

R1C1	EQ.INPUT!Id.
R1C4	EQ.SCRATCH!Sys._mass
R1C6	EQ.INPUT!XLFRAC
R1C8	EQ.INPUT!Report
R1C11	TEXT(EQ.INPUT!Olv EQ.INPUT!Frac._F,"0.0")&";; "&EQ.INPUT!Olv EQ.INPUT!Exc.
R1C13	TEXT(EQ.INPUT!Opx EQ.INPUT!Frac._F,"0.0")&";; "&EQ.INPUT!Opx EQ.INPUT!Exc.
R1C15	TEXT(EQ.INPUT!Cpx EQ.INPUT!Frac._F,"0.0")&";; "&EQ.INPUT!Cpx EQ.INPUT!Exc.
R1C17	TEXT(EQ.INPUT!Pla EQ.INPUT!Frac._F,"0.0")&";; "&EQ.INPUT!Pla EQ.INPUT!Exc.
R1C19	TEXT(EQ.INPUT!Spn EQ.INPUT!Frac._F,"0.0")&";; "&EQ.INPUT!Spn EQ.INPUT!Exc.
R1C21	TEXT(EQ.INPUT!Ilm EQ.INPUT!Frac._F,"0.0")&";; "&EQ.INPUT!Ilm EQ.INPUT!Exc.
R3C2	EQ.SCRATCH!T_max-273
R3C3	EQ.SCRATCH!f_O2
R3C4	EQ.SCRATCH!F_9
R4C2	EQ.SCRATCH!OLTP-273
R5C2	EQ.SCRATCH!OPXTP-273

R6C2	EQ.SCRATCH!CPXTP-273
R7C2	EQ.SCRATCH!PLTP-273
R8C2	EQ.SCRATCH!SPTP-273
R9C2	EQ.SCRATCH!OXTP-273
R10C2	EQ.SCRATCH!T_max-273
R10C3	EQ.SCRATCH!Sol._mass
R10C4	EQ.SCRATCH!Crystalised

Values of cells.

R1C1	"423-3-02 fc"
R1C3	"Sys. mass="
R1C4	6559.7908139126
R1C5	"Dec. factor"
R1C6	0.00025
R1C7	"Rep. factor"
R1C8	0.002
R1C9	"mode
R1C10	"Olivine"
R1C11	"0.0
R1C12	"Orthopx."
R1C13	"0.0
R1C14	"Clinopx."
R1C15	"0.0
R1C16	"Plagioclase"
R1C17	"0.0
R1C18	"Spinel"
R1C19	"0.0
R1C20	"Ilmenite"
R1C21	"0.0
R2C1	"Phase"
R2C2	"Temp."
R2C3	"F"
R2C4	"CUM"
R2C5	"Si"
R2C6	"Ti"
R2C7	"Al"
R2C8	"Fe2+"
R2C9	"Fe3+"
R2C10	"Mg"
R2C11	"Ca"
R2C12	"Na"
R2C13	"K"
R2C14	"Cr"
R2C15	"SiO2"
R2C16	"TiO2"
R2C17	"Al2O3"
R2C18	"FeO"
R2C19	"Fe2O3"
R2C20	"MgO"
R2C21	"CaO"
R2C22	"Na2O"
R2C23	"K2O"
R2C24	"Cr2O3"
R3C1	"Liquid"
R3C2	1186.0867408987
R3C3	-7.9393288093445
R3C4	0.15
R3C5	0.48314760922719
R3C6	0.0056402815700535
R3C7	0.18126983352793
R3C8	0.066036069143479
R3C9	0.013271931972652
R3C10	0.074121463395936
R3C11	0.095929463220843
R3C12	0.060835550939383
R3C13	0.017247797002537
R3C15	52.223196966751
R3C16	0.81064177423791
R3C17	16.619638968871
R3C18	8.534722439827

R3C19	1.9062966437869
R3C20	5.3758349238937
R3C21	9.6770154653204
R3C22	3.3913643558574
R3C23	1.4612884614553
R4C1	"Olivine"
R4C2	1148.0157323939
R5C1	"Orthopx."
R5C2	1120.1352427006
R6C1	"Clinopx."
R6C2	1125.3990840912
R7C1	"Plagioclase"
R7C2	1186.0867408987
R7C4	41.666666666667
R7C5	0.46488971247623
R7C7	0.33511028752377
R7C11	0.13511028752377
R7C12	0.064889712476233
R7C15	51.159873503727
R7C17	31.280934304474
R7C21	13.876302069571
R7C22	3.6828901222283
R8C1	"Spinel"
R8C2	1027.0002679825
R9C1	"Ilmenite"
R9C2	749.96355681767
R10C1	"Solid"
R10C2	1186.0867408987
R10C3	53.93622410044
R10C4	0.0082222475732072
R10C5	0.1937040468651
R10C7	0.13962928646824
R10C11	0.056295953134904
R10C12	0.02703738019843
R10C15	51.159873503727
R10C17	31.280934304474
R10C21	13.876302069571
R10C22	3.6828901222283

XL XREF - A PROGRAMME FOR GENERATING SOURCE LISTINGS OF EXCEL™ AND LOTUS™ WORKSHEETS.

Source Environment: ZBasic, version 4.01 or greater
Installed resources: 1 BNDL, 1 FREF, 1 ICN#, 1 ICON, 1 PICT, 2 vers, 1 XLrf

This programme was used to generate the source listings for all the Excel™ worksheets and macro programmes in this section. It translates in two passes a SYLK format file and generates a tab delimited, carriage return terminated TEXT file.

```
REM ** Excel Name Cross Referencer**
'© 1988 HR Ballard
DIM 255 SEARCH$,Record$, Name$, Ref$, Cells$(1200), Vals$(1200)
DIM 5 DR$,DC$,DX$,DY$
DIM T%,L%,B%,R%,WT%,WL%,WB%,WR%,t%,l%,b%,r%
'TRON B
WINDOW OFF
COORDINATE WINDOW
DEF MOUSE=-1
APPLE MENU "^1 About XLXRef..."
ON MENU GOSUB "MenuCheck"
WINDOW 1,"", (20,30)-(493,200), 2
"Here"
BUTTON 1,1,"Go get 'em!",(180,150)-(280,170),1
BUTTON 2,1,"Tell me more!?",(350,150)-(470,170),1
```

```
BUTTON 3,1,"Quit now!!",(5,150)-(105,170),1
Refs%=2:NVal%=1:For%=2:FVal%=1
BUTTON 4,Refs%,"Names", (105,85)-(170,100),2
BUTTON 6,For%,"Formulas", (305,85)-(385,100),2
BUTTON 5,NVal%,"Name values",(115,105)-(230,117),3
BUTTON 7,FVal%,"Formula values",(315,105)-(440,117),3

MENU ON
"Refresh1"
TEXT 2,18,1,64
PRINT@ (7,0) "Excel Cross Ref."
TEXT 3,12,2,0
PRINT@ (3,2) "Generates a listing of all defined names and formulas in an  "
PRINT@ (4,3) "Excel document  and their cell references and/or values.  "

DIALOG ON
"Idle"
IF DIALOG(0)<>1 THEN GOTO "Idle"
LONG IF DIALOG(1)=4
    Refs%=-Refs%+3
    BUTTON 4,Refs%
    IF Refs%=1 THEN BUTTON 5,1:NVal%=0 ELSE NVal%=1
    BUTTON 5,NVal%
    IF BUTTON(4)+BUTTON(6)=2 THEN BUTTON 1,0 ELSE BUTTON 1,1
    GOTO "Idle"
END IF

LONG IF DIALOG(1)=5
    NVal%=-NVal%+3
    BUTTON 5,NVal%
    GOTO "Idle"
END IF

LONG IF DIALOG(1)=6
    For%=-For%+3
    BUTTON 6,For%
    IF For%=1 THEN BUTTON 7,1:FVal%=0 ELSE FVal%=1
    BUTTON 7,FVal%
    IF BUTTON(4)+BUTTON(6)=2 THEN BUTTON 1,0 ELSE BUTTON 1,1
    GOTO "Idle"
END IF

LONG IF DIALOG(1)=7
    FVal%=-FVal%+3
    BUTTON 7,FVal%
    GOTO "Idle"
END IF

DIALOG OFF
MENU OFF
IF DIALOG(1)=2 THEN "Tellme"
IF DIALOG(1)=3 THEN SYSTEM

REM***Button logicals
Refs%=ABS(BUTTON(4)-1)
NVals%=ABS(BUTTON(5)-1)
For%=ABS(BUTTON(6)-1)
NFor%=ABS(BUTTON(7)-1)

CLS:TEXT 3,18,1,0
PRINT:PRINT "              Select a file to check:"
TEXT 3,12,0,0
INFIL$=FILES$(1,"TEXT",,V%)
CLS
IF LEN(INFIL$)=0 THEN GOTO "Refresh1"
CALL KILLCONTROLS(WINDOW(14))
OPEN "I",1,INFIL$,,V%
OUT$=INFIL$+MARKER$+".XLXR"
IF LEN(OUT$)=0 THEN END
OPEN "O",2,OUT$,,V%
```

```
CLS
PRINT@ (2,0) "Output file will be saved at the same directory level as: "
TEXT 3,12,1,0
PRINT@ (2,1) OUT$
TEXT 3,12,0,0
BEEP
DIALOG ON
BUTTON 8,1, "Yes", (190,49)-(255,69),3
BUTTON 9,1, "No", (290,49)-(355,69),3
PRINT@ (2,3) "Send output to printer?"
PRINT@ (2,6) "This output is routed directly to the printer without going through"
PRINT@ (2,7) "the printer driver and all formatting control is handled by the"
PRINT@ (2,8) "program. DO NOT SELECT THE PRINTER PORT IF APPLETALK IS"
PRINT@ (2,9) "CONNECTED!!"

WHILE DIALOG(0)<>1
WEND
DIALOG OFF
ANSWER=DIALOG(1)-7
LONG IF ANSWER=1
    BEEP
    PRINT@ (2,3) "Select an output port:          "
    DIALOG ON
    BUTTON 8,1,"Modem":BUTTON 9,1,"Printer"
    WHILE DIALOG(0)<>1
    WEND
    DIALOG OFF
    Port=-(DIALOG(1)-7)
END IF
CALL KILLCONTROLS(WINDOW(14))
IF ANSWER=1 THEN OPEN "C",Port,9600:HANDSHAKE PORT,-1:GOSUB "PRINTSET"
WINDOW 3,OUT$,(3,40)-(512,340), 1

TEXT 3,12,1,0
CURSOR 4

REM***Read file
Pass%=0
LONG IF Refs%
    GOSUB "Names"
    Mr%=r%-1:Mv%=v%-1
    GOSUB "PrintIt"
    RECORD 1,0
    TEXT 3,12,1,0
END IF

IF For% THEN GOSUB "Formulas":Mr%=r%-1:Mv%=v%-1:GOSUB "PrintIt"
CURSOR 0
GOTO "quit"


"Names"
r%=0:v%=0:Pass%=Pass%+1
PRINT@ (3,2) "Pass...  "
PRINT@ (6,2) Pass%
PRINT@ (3,3) "Parsing record number...          "
RecNum%=1
DO
    PRINT@ (14,3) RecNum%
    LINE INPUT #1, SEARCH$
    RecNum%=RecNum%+1
    GOSUB "FindNames"
UNTIL EOF(1)
RETURN

"FindNames"
    Find%=INSTR(1,SEARCH$,"NN;N")+4
    IF Find%<=4 THEN RETURN
    FindName%=INSTR(Find%,SEARCH$,";")-Find%
    Name$=MID$(SEARCH$,Find%,FindName%)
```

```
    Find%=INSTR(1,SEARCH$,";E")
    Find%=LEN(SEARCH$)-Find%-1
    Ref$=RIGHT$(SEARCH$,Find%)
    Record$=Ref$+CHR$(9)+Name$
    LONG IF LEFT$(Ref$,1)="R"
        Cells$(r%)=Record$
        r%=r%+1
    XELSE
        Vals$(v%)=Record$
        v%=v%+1
    END IF
RETURN

"Formulas"
r%=0:v%=0:Sub%=0:Pass%=Pass%+1
CLS
PRINT@ (3,2) "Pass...    "
PRINT@ (6,2) Pass%
PRINT@ (3,3) "Parsing record number...              "
RecNum%=1
DO
    PRINT@ (14,3) RecNum%
    PSEARCH$=SEARCH$
    LINE INPUT #1, SEARCH$
    RecNum%=RecNum%+1
    GOSUB "FindForm"
UNTIL EOF(1)
RETURN

"FindForm"
CRec%=INSTR(1,SEARCH$,"C;")
FRec%=INSTR(1,SEARCH$,"F;")
IF NOT(CRec%=1 OR FRec%=1) THEN RETURN

REM***Get differentials X and Y
Start%=INSTR(1,SEARCH$,";X")
LONG IF Start%<>0
    End%=INSTR(Start%+1,SEARCH$,";")
    SELECT CASE End%
        CASE 0
            DX$=RIGHT$(SEARCH$,LEN(SEARCH$)-Start%-1)
        CASE ELSE
            DX$=MID$(SEARCH$,Start%+2,End%-Start%-2)
    END SELECT
END IF
Start%=INSTR(1,SEARCH$,";Y")
LONG IF Start%<>0
    End%=INSTR(Start%+1,SEARCH$,";")
    SELECT CASE End%
        CASE 0
            DY$=RIGHT$(SEARCH$,LEN(SEARCH$)-Start%-1)
        CASE ELSE
            DY$=MID$(SEARCH$,Start%+2,End%-Start%-2)
    END SELECT
END IF

REM***Get formula
Find%=INSTR(1,SEARCH$,";E")
Check%=INSTR(Find%+1,SEARCH$,";")
LONG IF Find%>0
    LONG IF Check%-Find%<>2
        Name$=RIGHT$(SEARCH$,LEN(SEARCH$)-Find%-1)
        LONG IF Name$<>"0"
            Cells$(r%)="R"+DY$+"C"+DX$+CHR$(9)+Name$
            r%=r%+1
        END IF
    END IF
END IF

REM***Get formula values
```

```
FindM%=INSTR(1,SEARCH$,";M{")
IF FindM%<>0 THEN GOTO "Array"
Find%=INSTR(1,SEARCH$,";K")
LONG IF Find%>0
    End%=INSTR(Find%+1,SEARCH$,";")
    LONG IF End%=0
        Name$=RIGHT$(SEARCH$,LEN(SEARCH$)-Find%-1)
    XELSE
        Name$=MID$(SEARCH$,Find%+2,End%-Find%-2)
    END IF
    IF Name$="0" THEN RETURN
    IF Name$="" THEN RETURN
    Vals$(v%)="R"+DY$+"C"+DX$+CHR$(9)+Name$
    v%=v%+1
END IF
RETURN

"Array"
Start%=INSTR(1,SEARCH$,";R")
LONG IF Start%<>0
    End%=INSTR(Start%+1,SEARCH$,";")
    DR$=MID$(SEARCH$,Start%+1,End%-Start%-1)
END IF
Start%=INSTR(1,SEARCH$,";C")
LONG IF Start%<>0
    End%=INSTR(Start%+1,SEARCH$,";")
    DC$=MID$(SEARCH$,Start%+1,End%-Start%-1)
END IF
Name$=RIGHT$(SEARCH$,LEN(SEARCH$)-FindM%-1)
Vals$(v%)="R"+DY$+"C"+DX$+":"+DR$+DC$+CHR$(9)+Name$
v%=v%+1
RETURN

"PrintIt"
CLS
TEXT 4,9,0,0
LONG IF Pass%=1
    PRINT "Cross reference of Excel file "+INFIL$
    PRINT  #2,"Cross reference of Excel file "+INFIL$
END IF
PRINT:PRINT #2,

IF Refs% THEN GOSUB "PNR":RETURN
IF For% THEN GOSUB "PCF":RETURN

"PNR"
PRINT "Names with cell references"
PRINT #2,"Names with cell references"
IF ANSWER=1 THEN PRINT #Port,"Names with cell references"+CHR$(10)+CHR$(13)
FOR r%=0 TO Mr%
    PRINT Cells$(r%):PRINT #2, Cells$(r%)
    LONG IF ANSWER=1
        Tab%=INSTR(1,Cells$(r%),CHR$(9))
        Cells$(r%)=LEFT$(Cells$(r%),Tab%-1)+"    "+RIGHT$(Cells$(r%),LEN(Cells$(r%))-Tab%+1)
        PRINT #Port, Cells$(r%)+CHR$(13);CHR$(10)
    END IF
NEXT
IF NVals% THEN GOSUB "PNV"
Refs%=0
RETURN

"PNV"
PRINT:PRINT #2,
PRINT "Names with values."
PRINT #2,"Names with values."
IF ANSWER=1 THEN PRINT #Port,"Names with values."+CHR$(10)+CHR$(13)
FOR v%=0 TO Mv%
    PRINT Vals$(v%):PRINT #2, Vals$(v%)
    LONG IF ANSWER=1
        Tab%=INSTR(1,Vals$(v%),CHR$(9))
```

```
        Vals$(v%)=LEFT$(Vals$(v%),Tab%-1)+"    "+RIGHT$(Vals$(v%),LEN(Vals$(v%))-Tab%+1)
        PRINT #Port, Vals$(v%)+CHR$(13);CHR$(10)
    END IF
NEXT
RETURN

"PCF"
IF Pass%=2 THEN PRINT:PRINT #2,
PRINT "Cells with formulas."
PRINT #2,"Cells with formulas."
IF ANSWER=1 THEN PRINT #Port,"Cells with formulas."+CHR$(10)+CHR$(13)
FOR r%=0 TO Mr%
    PRINT Cells$(r%):PRINT #2, Cells$(r%)
    LONG IF ANSWER=1
        Tab%=INSTR(1,Cells$(r%),CHR$(9))
        Cells$(r%)=LEFT$(Cells$(r%),Tab%-1)+"    "+RIGHT$(Cells$(r%),LEN(Cells$(r%))-Tab%+1)
        PRINT #Port, Cells$(r%)+CHR$(13);CHR$(10)
    END IF
NEXT
IF NFor% THEN GOSUB "PCV"
RETURN

"PCV"
PRINT:PRINT #2,
PRINT "Values of cells."
PRINT #2,"Values of cells."
IF ANSWER=1 THEN PRINT #Port,"Values of cells."+CHR$(10)+CHR$(13)
FOR v%=0 TO Mv%
    PRINT Vals$(v%):PRINT #2,Vals$(v%)
    LONG IF ANSWER=1
        Tab%=INSTR(1,Vals$(v%),CHR$(9))
        Vals$(v%)=LEFT$(Vals$(v%),Tab%-1)+"    "+RIGHT$(Vals$(v%),LEN(Vals$(v%))-Tab%+1)
        PRINT #Port, Vals$(v%)+CHR$(13);CHR$(10)
    END IF
NEXT
RETURN

"PRINTSET"
WIDTH LPRINT -2
PRINT #Port, CHR$(27)+CHR$(128)+CHR$(48)
PRINT #Port, CHR$(27)+CHR$(76)+"010"
PRINT #Port, CHR$(27);CHR$(97);CHR$(48)
PRINT #Port, CHR$(27);CHR$(110)
PRINT #Port, CHR$(27);CHR$(33)
PRINT #Port,CHR$(13)+CHR$(10)
PRINT #Port,CHR$(13)+CHR$(10)
PRINT #Port, OUT$;CHR$(10)
PRINT #Port, INFIL$;CHR$(13);CHR$(10)
PRINT #Port,CHR$(13)+CHR$(10)
PRINT #Port,CHR$(13)+CHR$(10)
PRINT #Port, CHR$(27);CHR$(34)
PRINT #Port, CHR$(27) CHR$(69)
RETURN

"quit"
IF ANSWER=1 THEN PRINT #Port, CHR$(12):CLOSE #Port
CLOSE #1
CLOSE #2
BEEP
TEXT 3,9,1,0:PRINT  "Jeez, that was quick!!"
DIALOG ON
BUTTON 10,1,"Go again?",(350,200)-(470,220),1
BUTTON 11,2,"Quit to Finder",(350,250)-(470,270),1
WHILE DIALOG(0)<>1
WEND
DIALOG OFF
CALL KILLCONTROLS(WINDOW(14))
WINDOW CLOSE 3
IF DIALOG(1)=10 THEN "Here"
SYSTEM
```

```
"Tellme"
WINDOW 3, "Tell me more!",(10,30)-(500,320), 4

"RePaint"
TEXT 3,12,0,0
PRINT
PRINT " This program was written to assist in documenting Excel Worksheets and"
PRINT " Macros by extracting references and values from Defined Names and listing"
PRINT " formulas by cell reference. The file to be read must be saved in SYLK format"
PRINT " (see the Save As... dialog box in Excel) and will work with SYLK files from"
PRINT " other computers."
PRINT
PRINT " References are given in RC format, e.g. R1C1 for row 1, column 1 and ranges"
PRINT " of cells are given as the top left and bottom right cells separated by colons."
PRINT " Values listed are those that were current at the time the file was saved."
PRINT " Arrays are enclosed in {}'s"
PRINT " The generated text file of the listing is tab delimited so it can be read by"
PRINT " Excel or any word processor or text editor."
PRINT " Maximum number of each type is 1200. The program checks that string"
PRINT " lengths and array bounds are not exceeded.
TEXT 3,10,1,0
PRINT@ (14,20) " ©H.R. Ballard, 1988."
BUTTON 5,2,"Continue", (400,250)-(470,270),1

DIALOG ON
"Idle2"
 IF DIALOG(0)<>1 THEN "Idle2"
DIALOG OFF
WINDOW CLOSE 3
GOTO "Refresh1"

"MenuCheck"
IF MENU(0)=255 AND MENU(1)=1 THEN "About" ELSE RETURN

"About"
CALL HIDECURSOR
WT%=0:WL%=0:WB%=342:WR%=512
t%=120:l%=319:b%=271:r%=471
WINDOW #10,"",(0,0)-(512,342),3
PEN 5,10,1,8,0

REM GET PICT RESOURCE
RESNUM%=1
Pic&=FN GETPICTURE(RESNUM%)
CALL DETACHRESOURCE(Pic&)

REM BLACKOUT WINDOW
CALL PAINTRECT(WT%)
X%=320:Y%=120:LX%=320:LY%=120

REM OUTLINE RECTANGLE
CALL MOVETO(0,0)
FOR I=1 TO 100
    SELECT CASE
        CASE I<=25
            Y%=Y%+6
        CASE (I>25 AND I<=50)
            X%=X%+6
        CASE (I>50 AND I<=75)
            Y%=Y%-6
        CASE (I>75 AND I<=100)
            X%=X%-6
    END SELECT
    PEN 1,1,1,10,22
    CALL LINETO(X%,Y%)
    CALL LINETO(0,0)
    PEN 1,1,1,8,19
    PLOT LX%,LY% TO X%,Y%
    LX%=X%:LY%=Y%
```

```
NEXT
RL%=-5
RX%=X%-5:RY%=Y%+150
CALL MOVETO(0,0)

REM FILL RECTANGLE
DO
PEN 5,15,1,10,9
CALL LINETO(RX%,RY%)
CALL LINETO(0,0)
PEN 5,10,1,8,11
CALL PAINTRECT(T%)
SELECT CASE
    CASE RX%<X%
        RL%=-RL%
        RY%=RY%-15
        RX%=RX%+5
    CASE RX%>X%+145
        RL%=-RL%
        RY%=RY%-15
        RX%=RX%-5
END SELECT
T%=RY%:L%=RX%:B%=RY%+15:R%=RX%+5
RX%=RX%+RL%
UNTIL RY%<Y%
DELAY 1000


REM MOVE RECTANGLE TO CENTRE SCREEN WITH BIT MAP
Odx%=-8 : Ody%=-3
FOR I=1 TO 18
    PEN 1,1,1,8,0
    CALL PAINTRECT(t%)
    CALL OFFSETRECT(t%,Odx%,Ody%)
    DELAY 17
    PEN 1,1,1,8,11
    CALL PAINTRECT(t%)
NEXT

REM BLOWUP RECTANGLE
FOR I=1 TO 19
    Idx%=-2 : Idy%=-2
PEN 1,1,1,8,I
    CALL INSETRECT(t%,Idx%,Idy%)
    CALL PAINTRECT(t%)
NEXT

CALL DRAWPICTURE(Pic&,t%)
DELAY 2000

REM ZOOM OUT PICT
FOR I=1 TO 20
PEN 1,1,1,8,19
CALL INVERTRECT(t%)
CALL INSETRECT(t%,15,15)
CALL PAINTRECT(t%)
CALL DRAWPICTURE(Pic&,t%)
DELAY 10
NEXT
WINDOW CLOSE #10
CALL SHOWCURSOR
MENU
GOTO "Refresh1"
END
```

DIGITIZER - A PROGRAMME FOR GENERATING NUMERICAL COORDINATES FROM A POINTING DEVICE (MOUSE, DIGITIZING TABLET, ETC.).

Source Environment: ZBasic, version 4.01 or greater
Installed resources: 1 BNDL, 1 Digi, 4 DITL, 4 DLOG, 1 FOND, 1 FONT, 1 FREF, 1 ICN#, 8 PICT, 2 vers

Digitizer generates a tab delimited, carriage return terminated TEXT file of numerical screen coordinates from a pointing device. It has the following capabilities:

- attaching a text string to any point or group of points; by including tab characters multiple values can be assigned to delimited fields.
- choice of screen origins; upper or lower left.
- translation of the screen origin to any position.
- scaling of screen pixel coordinates so real-space values are displayed and saved.
- automatically uses the full screen of any monitor.
- interactive data file editing (with an appropriate Desk Accessory) and re-plotting.

```
'***Digitizer for generating numerical data from the mouse
'© 1988 HR Ballard
'***Version 2.5
'***Digitizer for generating numerical data from the mouse

WINDOW OFF
COORDINATE WINDOW
WIDTH -2:DEF TAB 2
APPLE MENU "About Digitizer..."

DIM Y%,X%, KeyOn%(7), Picture&, Pic&, Pic2&, DIHndl&
DIM Dummy$, Info$, 100 alt$, 32 File$, Location$, 12 Use$, CX$, CY$
Use$="+###,###.###"

VSIZE%= PEEK WORD(PEEK LONG(&904)-116)  ' Vertical size of screen
HSIZE%= PEEK WORD(PEEK LONG(&904)-114)  ' Horizontal size of screen
GRAY&=PEEK LONG(&9EE) ' Gets gray region of desktop
OldGrayRgn&=FN NEWRGN ' Gets a new handle for region
CALL COPYRGN(GRAY&,OldGrayRgn&) ' Gets a copy of standard desktop
CALL SETRECTRGN(GRAY&,0,0,HSIZE%,VSIZE%) ' Sets desktop to full screen
WINDOW#1 ,,(0,0)-(HSIZE%,20),3
WINDOW CLOSE 1

REM ** Open Resource file FOR DEBUGGING ONLY! Install resources into application.
'FName$="ResourceLib"
'RefNum%=FN OPENRESFILE(FName$)

dID=22125:Dsto&=0:BWptr&=-1
DPtr&=FN GETNEWDIALOG(dID,Dsto&,BWptr&)
"Dialog0Idle"
CALL MODALDIALOG(0,item%)
IF item%<>1 THEN GOTO "Dialog0Idle"
CALL DISPOSDIALOG(DPtr&)
DIALOG OFF:IHndl&=MEM(-1)

"NewFile"
CURSOR 0:FLUSHEVENTS
File$=FILES$(0,"Name the output file:","DigitOut",vol%)
IF File$="" THEN "Quit"

REM **Scaling Dialog
dID=19734:Dsto&=0:BWptr&=-1
DPtr&=FN GETNEWDIALOG(dID,Dsto&,BWptr&)
REM ** Select scale text
CALL SELITEXT(DPtr&,4,0,20)
```

```
"Dialog1Idle"
CALL MODALDIALOG(0,item%)
IF item%<>1 THEN GOTO "Dialog1Idle"
item%=4
CALL GETDITEM(DPtr&,item%,IType%,IHndl&,Dummy$)
CALL GETITEXT(IHndl&,Dummy$)
SF!=VAL(Dummy$)
IF SF!<=0 THEN BEEP:GOTO "Dialog1Idle"
CALL DISPOSDIALOG(DPtr&)
DIALOG OFF:IHndl&=MEM(-1)

REM ** Origin Dialog
dID=961:Dsto&=0:BWptr&=-1
DPtr&=FN GETNEWDIALOG(dID,Dsto&,BWptr&)
REM ** Set origin button to LL
LLSelected%=1
CALL GETDITEM(DPtr&,5,IType%,I5Hndl&,Dummy$)
CALL SETCTLVALUE(I5Hndl&,1)
CALL DRAW1CONTROL(I5Hndl&)
REM ** Select X text
CALL SELITEXT(DPtr&,2,0,20)
"Dialog2Idle"
CALL MODALDIALOG(0,item%)
event%=item%
item%=2
CALL GETDITEM(DPtr&,item%,IType%,IHndl&,Dummy$)
CALL GETITEXT(IHndl&,Dummy$)
DX!=VAL(Dummy$)
item%=3
CALL GETDITEM(DPtr&,item%,IType%,IHndl&,Dummy$)
CALL GETITEXT(IHndl&,Dummy$)
DY!=VAL(Dummy$)
LONG IF event%=8 OR event%=5
    CALL GETDITEM(DPtr&,8,IType%,I8Hndl&,Dummy$)
    CALL GETDITEM(DPtr&,5,IType%,I5Hndl&,Dummy$)
    TLSelected%=FN GETCTLVALUE(I8Hndl&)
    LLSelected%=FN GETCTLVALUE(I5Hndl&)
    CALL SETCTLVALUE(I8Hndl&,LLSelected%)
    CALL SETCTLVALUE(I5Hndl&,TLSelected%)
    CALL DRAW1CONTROL(I8Hndl&)
    CALL DRAW1CONTROL(I5Hndl&)
    LLSelected%=-LLSelected%+1
END IF
IF event%<>1 THEN GOTO "Dialog2Idle"
"End"
CALL DISPOSDIALOG(DPtr&)
DIALOG OFF:IHndl&=MEM(-1)

Pts%=0
OPEN "O",1,File$,,vol%
WINDOW#1 ,,(0,0)-(HSIZE%,VSIZE%),3 ' Sets Window to full screen size
GET WINDOW #1, Wptr&
CURSOR 2:CLS

"MouseTrap"
TEXT 255,9,0,0:' Uses installed modified Geneva font for arrows.
IHndl&=MEM(-1)
DO
    CALL GETMOUSE(Y%)
    CALL LOCALTOGLOBAL(Y%)
    WHERE=FN FINDWINDOW(Y%,Wptr&)
    IF LLSelected%=1 THEN PY%=VSIZE%-Y% ELSE PY%=Y%
    PX%=X%
    LONG IF X%<>LX% OR Y%<>LY%
        CX!=(PX%+DX!*SF!)/SF!:CY!=(PY%+DY!*SF!)/SF!
        LOCATE 0,0:CLS LINE
        LONG IF alt$=""
            PRINT@ (0,0) "SF:"+STR$(SF!)+"  PIF:"+STR$(Pts%);USING Use$;CX!;" ¤";USING Use$;CY!;"/
        XELSE
            PRINT@ (0,0) "SF:"+STR$(SF!)+"  PIF:"+STR$(Pts%);USING Use$;CX!;" ¤";USING Use$;CY!;"
```

```
/"," • ";alt$
        END IF
        PRINT@ (0,0) Info$
        LX%=X%:LY%=Y%
    END IF
    LONG IF FN BUTTON
        CALL GETKEYS(KeyOn%(0))
        ModKey%=KeyOn%(3)
        SELECT CASE ModKey%
            CASE 1
                LOCATE 0,0:CLS LINE
                INPUT@ (0,0) "3D set input. Attach to points following: "; alt$
                ThreeD%=1
            CASE 2
                BEEP
                PLOT X%,Y%:Pts%=Pts%+1
                LOCATE 0,0:CLS LINE
                INPUT@ (0,0) "3D input. Attach to this point: "; alt$
                IF CX!>=0 THEN CX$=RIGHT$(STR$(CX!),LEN(STR$(CX!))-1) ELSE CX$=STR$(CX!)
                IF CY!>=0 THEN CY$=RIGHT$(STR$(CY!),LEN(STR$(CY!))-1) ELSE CY$=STR$(CY!)
                Location$=CX$+CHR$(9)+CY$
                IF alt$<>"" THEN Location$=Location$+CHR$(9)+alt$
                alt$=""
                Location$=Location$+CHR$(13)
                LocLen%=LEN(Location$)
                WRITE #1, Location$;LocLen%
            CASE 4
                CLS
            CASE -32764
                Forever=1
                DA=1
            CASE -32763
                Forever=1
                CLOSE #1
            CASE -32768
                Forever=1
                NewFile=1
                CLOSE 1
                WINDOW CLOSE 1
            CASE ELSE
                BEEP
                PLOT X%,Y%:Pts%=Pts%+1
                IF CX!>=0 THEN CX$=RIGHT$(STR$(CX!),LEN(STR$(CX!))-1) ELSE CX$=STR$(CX!)
                IF CY!>=0 THEN CY$=RIGHT$(STR$(CY!),LEN(STR$(CY!))-1) ELSE CY$=STR$(CY!)
                Location$=CX$+CHR$(9)+CY$
                IF ThreeD%=1 AND alt$<>"" THEN Location$=Location$+CHR$(9)+alt$
                Location$=Location$+CHR$(13)
                LocLen%=LEN(Location$)
                WRITE #1, Location$;LocLen%
        END SELECT
    END IF
UNTIL Forever
IF NewFile=1 THEN NewFile=0:Forever=0:GOTO "NewFile"
IF DA=1 THEN Forever=0:DA=0:GOTO "DAHandle"

"Quit"
WINDOW CLOSE #1
CALL DISPOSERGN(OldGrayRgn&)
'Throw away the old handles
CALL DRAWMENUBAR
END

"DAHandle"
CLOSE 1
WINDOW CLOSE 1
EDIT MENU 2
CALL DRAWMENUBAR
CURSOR 0
WINDOW 2,"",(156,280)-(356,335),2
BUTTON 1,1,"Return to full screen",(2,30)-(198,53),1
```

```
TEXT 3,14,1,0
PICTURE ON:CALL SHOWPEN
PRINT@ (4,0) "Digitizer"
PICTURE OFF, Pic2&
WINDOW PICTURE 2, Pic2&
FLUSHEVENTS:DIALOG ON:MENU ON
ON MENU GOSUB "Menu"
DO
UNTIL DIALOG(0)=1
DIALOG OFF:MENU OFF
KILL PICTURE Pic2&
OPEN "A",1,File$,,vol%
RECORD 1,0
WINDOW CLOSE 2
WINDOW#1 ,,(0,0)-(HSIZE%,VSIZE%),3
GET WINDOW #1, Wptr&
CURSOR 2
TEXT 255,9,0,0:' Uses installed modified Geneva font for arrows.
LONG IF EOF(1)
    Pts%=0
XELSE
    NumRecs%=0
    SELECT CASE LLSelected%
        CASE 0
            DO
                LINE INPUT #1, Dummy$
                PlotX%=(VAL(Dummy$)-DX!)*SF!
                PlotY%=(VAL(MID$(Dummy$,INSTR(0,Dummy$,CHR$(9))+1))-DY!)*SF!
                PLOT PlotX%,PlotY%
                NumRecs%=NumRecs%+1
            UNTIL EOF(1)
            Pts%=NumRecs%
        CASE 1
            DO
                LINE INPUT #1, Dummy$
                PlotX%=(VAL(Dummy$)-DX!)*SF!
                PlotY%=VSIZE%-((VAL(MID$(Dummy$,INSTR(0,Dummy$,CHR$(9))+1))-DY!)*SF!)
                PLOT PlotX%,PlotY%
                NumRecs%=NumRecs%+1
            UNTIL EOF(1)
            Pts%=NumRecs%
        END SELECT
END IF
GOTO "MouseTrap"

"Menu"
MENU OFF
LONG IF MENU(0)=255 AND MENU(1)=1
    dID=27353:Dsto&=0:BWptr&=-1
    DPtr&=FN GETNEWDIALOG(dID,Dsto&,BWptr&)
    "Dialog0Idle"
    CALL MODALDIALOG(0,item%)
    IF item%<>1 THEN GOTO "Dialog0Idle"
    CALL DISPOSDIALOG(DPtr&)
    DIALOG OFF:IHndl&=MEM(-1)
END IF
MENU ON
RETURN
```

DATACONVERTER - A PROGRAMME FOR RE-FORMATTING DATA TRANSFERRED TO/FROM OTHER COMPUTERS TO THE MACINTOSH.

Source Environment: ZBasic, version 4.01 or greater
Installed resources: 1 BNDL, 2 FREF, 2 ICN#, 1 PICT, 2 vers, 1 Xrf_

This programme originally started as two separate programmes which were pooled together into the one application. One part grew out of the desire to transfer analysis data directly from the X-ray flouresence unit controlled by an NEC computer to the Macintosh in a form that could be immediately used in an EXCEL™ database. A programme was written by Roy Johnston to arrange the output data on the NEC into a row-ordered format which was then downloaded to the Macintosh and run through DataConverter which stripped the quotes, leading and trailing spaces and replaced the comma field delimiters with tabs (ASCII 9). The resulting transformed text file is then in a format Excel™ understands.

The other part of the programme resulted from a problem encountered in telecommunications with the campus VAX mainframe. The VAX uses both linefeed characters (ASCII 10) and carriage returns (ASCII 13) to signal end-of-lines. The Macintosh uses only carriage returns so embedded linefeeds can become a problem when files brought from the VAX are edited on the Mac and then sent back to the VAX If the telecommunications programme on the Mac strips linefeeds during transfer from the VAX, when the file is sent back to the VAX the whole file is considered a single line and usually exceeds the 32 000 character limit. To remedy this problem, DataConverter has an option to add linefeeds at the end of each line of a file before it is sent to the VAX.

```
REM **Data Converter **
'© 1988 HR Ballard
REM **Strips trailing spaces, quotes and replaces commas with tab characters.**
REM **Adds linefeeds.**
WINDOW OFF
COORDINATE WINDOW

REM **Open resource file during debugging ONLY!!
'FName$="ResourceLib"
'RefNum%=FN OPENRESFILE(FName$)
'TRON B

DEF MOUSE=1
MENU 1,0,1,"File"
MENU 1,1,0,"Open..."
MENU 1,3,1,"Quit"
MENU 2,0,1,"Convert"
MENU 2,1,1,"Add linefeeds"
MENU 2,2,1,"Remove quotes from strings, replace commas with tabs"
APPLE MENU "About DataConverter..."
ON MENU GOSUB "menuHandle"

"menuIdle"
MENU ON
DO
UNTIL menuchoice

"menuHandle"
MENU OFF
menu=(MENU(0)-1)*3+MENU(1)
IF menu=763 THEN menu=6
ON menu GOSUB "File...","dummy","Quit","AddLF","RQRC","About..."
IF LF OR RC THEN MENU 1,1,1 ELSE MENU 1,1,0
CURSOR 0
RETURN
```

```
"About..."
MENU
dID=18049:Dsto&=0:BWptr&=-1
DPtr&=FN GETNEWDIALOG(dID,Dsto&,BWptr&)
"Dialog0Idle"
CALL MODALDIALOG(0,item%)
IF item%<>1 THEN GOTO "Dialog0Idle"
CALL DISPOSDIALOG(DPtr&)
DIALOG OFF:IHndl&=MEM(-1)
RETURN

"File..."
MENU
INFIL$=FILES$(1,"TEXT",,V%)
IF LEN(INFIL$)=0 THEN RETURN
CURSOR 4
OPEN "I",1,INFIL$,,V%
Out$=INFIL$+".DCF"
OPEN "O",2,Out$,,V%
GOSUB "Q&C"
RETURN

"dummy"
RETURN

"Quit"
SYSTEM

"AddLF"
MENU
IF LF THEN LF=0:MENU 2,1,1 ELSE LF=1:MENU 2,1,2
RETURN

"RQRC"
MENU
IF RC THEN RC=0:MENU 2,2,1 ELSE RC=1:MENU 2,2,2
RETURN

"Q&C"
WINDOW 1,"",(100,100)-(412,150),4
RecNumber%=0
TEXT 3,12,1,0
PRINT@ (1,1) "Processing record number..."
Space$=CHR$ (32)+CHR$ (34)
WHILE NOT EOF (1)
    RecNumber%=RecNumber%+1
    PRINT@ (14,1) RecNumber%
    LINE INPUT #1, Record$
    LONG IF RC
        Long%=LEN (Record$)
        Find%=INSTR (1,Record$,Space$)
        WHILE Find%<>0
            Record$=LEFT$ (Record$,Find%-1)+MID$ (Record$,Find%+1,Long%)
            Find%=INSTR (Find%-3,Record$,Space$)
        WEND
        Find%=INSTR (1,Record$,CHR$ (34))
        WHILE Find%<>0
            Record$=LEFT$ (Record$,Find%-1)+""+MID$ (Record$,Find%+1,Long%)
            Find%=INSTR (Find%,Record$,CHR$ (34))
        WEND
        Find%=INSTR (1,Record$,CHR$ (44))
        WHILE Find%<>0
            Record$=LEFT$ (Record$,Find%-1)+CHR$ (9)+MID$ (Record$,Find%+1,Long%)
            Find%=INSTR (Find%,Record$,CHR$ (44))
        WEND
    END IF
    IF LF THEN Record$=Record$+CHR$(13)+CHR$(10) ELSE Record$=Record$+CHR$(13)
    RecordLen%=LEN (Record$)
    WRITE #2, Record$;RecordLen%
WEND
```

```
CLOSE 1:CLOSE 2
WINDOW CLOSE 1
BEEP:BEEP
RETURN
END
```

FFT - FORTRAN FILE TRANSLATOR.

Source Environment: ZBasic, version 4.01 or greater
Installed resources: none, not compiled to application.

This programme was written for Dr. A.F. Cooper to translate data sent to him from a colleague which was produced by a mainframe FORTRAN programme into an Excel™ format.

```
REM ** FORTRAN File Translator**
'© 1988 HR Ballard
REM **For A.F. Cooper**
WINDOW OFF
'TRON B
COORDINATE WINDOW
DEF MOUSE=1
DIM 20 INFIL$ (20), V% (20), 255 Record$, NewRecord$, F$, Title$, FieldList$

LONG FN RemSpace$ (X$)
    WHILE ASC(RIGHT$(X$,1))=32
    X$=LEFT$(X$,LEN(X$)-1)
    WEND
END FN =X$

DEF FN LeadNumSpace$ (XI)=RIGHT$(STR$(XI),LEN(STR$(XI))-1)

WINDOW 1,"", (20,30)-(493,200), 2
"Here"
CLS
Me$="by HR Ballard"
X%=1
TEXT 3,9,0,0
WHILE X%<14
        YMe$=MID$(Me$,X%,1)
        PRINT@ (45,X%-1) YMe$
        X%=X%+1
WEND
TEXT 2,18,1,0
PRINT@ (4,0)  "The Funky FORTRAN formatter."
TEXT 3,14,1,0
PRINT@ (4,2) "Select a file to format:"
TEXT 3,12,0,0
NumFiles%=0
"Select"
INFIL$ (NumFiles%)=FILES$(1,"TEXT",,Vol%)
IF INFIL$ (NumFiles%)="" AND NumFiles%=0 THEN END
IF INFIL$ (NumFiles%)="" THEN GOTO "Open"
V% (NumFiles%)=Vol%
NumFiles%=NumFiles%+1
GOTO "Select"
"Open"
OpenFiles%=0
DO
OPEN "I",1,INFIL$ (OpenFiles%),,V% (OpenFiles%)
Out$=INFIL$ (OpenFiles%)+".FFT"
CLS
PRINT@ (2,0) "Output file will be saved in the same folder and named: "
TEXT 3,12,1,0
PRINT@ (2,1) Out$
OPEN "O",2,Out$,,V% (OpenFiles%)
```

```
RecNumber%=0
PRINT@ (2,3) "Processing record number..."
LINE INPUT #1, Record$
    Title$=FN RemSpace$(Record$)
    Title$=Title$+CHR$(13)
    FieldList$=CHR$(9)
    LINE INPUT #1, Record$
    NumFields%=VAL(RIGHT$(Record$,3))
    Count%=0
    DO
        LINE INPUT #1, Record$
        Fields%=0
        DO
            F$=MID$(Record$,Fields%*6+1,6)
            F$=FN RemSpace$(F$)
            FieldList$=FieldList$+CHR$(9)+F$
            Count%=Count%+1:Fields%=Fields%+1
        UNTIL (Count%=NumFields% OR Fields%=12)
    UNTIL Count%=NumFields%
    FieldList$=FieldList$+CHR$(13)
    Title%=LEN(Title$)
    FieldList%=LEN(FieldList$)
WRITE#2, Title$;Title%,FieldList$;FieldList%
LINE INPUT #1, Record$
WHILE NOT EOF (1)
    RecNumber%=RecNumber%+1
    PRINT@ (14,3) RecNumber%
    LINE INPUT #1, Record$
    SampleId$=LEFT$(Record$,16)
    SampleId$=FN RemSpace$ (SampleId$)
    SampleType$=MID$(Record$,24)
    SampleType$=FN RemSpace$ (SampleType$)
    NewRecord$=SampleId$+CHR$(9)+SampleType$
    NewRecordLen%=LEN(NewRecord$)
    WRITE#2, NewRecord$;NewRecordLen%
    NewRecord$=""

    Count%=0
    DO
        LINE INPUT #1, Record$
        Fields%=0
        DO
            F! =VAL(MID$(Record$,Fields%*8+1,8))
            IF F!=0 THEN F$="" ELSE F$=STR$ (F!)
            IF LEFT$(F$,1)=CHR$(32) THEN F$=FN LeadNumSpace$ (F!)
            NewRecord$=NewRecord$+CHR$(9)+F$
            Fields%=Fields%+1:Count%=Count%+1
        UNTIL (Count%=NumFields% OR Fields%=9)
    UNTIL Count%=NumFields%
NewRecord$=NewRecord$+CHR$(13)
NewRecordLen%=LEN (NewRecord$)
WRITE#2, NewRecord$;NewRecordLen%
NewRecord$=""
WEND
RESET
BEEP:BEEP
OpenFiles%=OpenFiles%+1
UNTIL OpenFiles%=NumFiles%
GOTO "Here"
END
```

XLFRAC - A LEAST SQUARES MASS BALANCE PROGRAM.

Source Environment: Microsoft BASIC, version 3.00 or greater
Installed resources: none, not compiled to application.

The calculation routines of this program were translated from an original FORTRAN program by J. Nicholls, University of Calgary, Alberta, Canada, which had been subsequently modified and published by Stormer and Nicholls (1978). In porting it to the Macintosh the interface had to be completely re-designed for keyboard, clipboard and file input. A batch mode option was added later. There are a number of "help screens" for the program which are not documented here. XLFRAC was used for initial investigations into fractionation models for the Mantle Volcanics Formation intrusive rocks.

```
REM*****XLFRAC version 1.6*****
CLEAR

REM*****DIMENSION VARIABLES AND ARRAYS*****
DIM AN(15,15), BN(15,15), F(15), STD(15), FF(15,1), CN(15,15), P(15), PN(15), OAN(15,15), OAN$(15,15)
DIM X(15), XP(15), Y(15), YY(15), D(15), PHASE$(15), OXIDE$(15), CN$(15,15), DUMMY$(50)
DIM SUMTOT(15), XN(15), IPIVOT(15), index(15,2), PIVOT(15), A(15,15), B(15,15)
filex=0 : ESC$=CHR$(27)

REM*****START*****
start:
BUTEST=0
    IF filex=1 THEN GOSUB FILEIN : ON modtype GOTO CONSTRAINED,UNCONSTRAINED
    IF filex=2 THEN GOTO OUTBUT

REM*****MENU*****
OPENFRAME:
    MENU 10,0,1, "Information"
    MENU 10,1,1, "References"
    MENU 10,2,1, "Help"
    MENU 10,3,1, "I/O"
    ON MENU GOSUB MENUCHK : MENU ON
    WINDOW 1, "OUTPUT", (7,27)-(505,332), 2
    OPEN "DD 20:BASIC:Magma modeling:XLFRAC Help:XLFRACPict" FOR INPUT AS #1
    Image$=INPUT$(LOF(1),1)
    CLOSE #1
    GOSUB FRAME1 : GOTO IOBUT


REM*****PRINT OPENING FRAME*****
FRAME1:
    CLS
    PICTURE (93,18), Image$
RETURN

TIFTT:
GOSUB FRAME1 : RESET : filex=0 : fileopen=0

REM*****I/O BUTTONS*****
IOBUT:
BUTTON 1,1, "Clipboard", (70,260)-(170,290)
BUTTON 2,1, "Keyboard", (200,260)-(300,290)
BUTTON 3,1, "File", (330,260)-(430,290)
CALL TEXTFONT (3) : CALL TEXTSIZE (12) : CALL TEXTFACE (1)
LOCATE 15,20 : PRINT "Select an input mode."
    WHILE DIALOG(0)<>1 : WEND
    bellybutton=DIALOG(1)
    BUTTON CLOSE 1 : BUTTON CLOSE 2 : BUTTON CLOSE 3
    IF bellybutton=3 THEN GOSUB Extype
    GOTO OUTBUT

REM*****FILE INPUT RUN MODE AND SELECT FILE*****
Extype:
    LOCATE 15,20 : PRINT "                    "
    LOCATE 15,20 : PRINT "Choose a run mode."
    BUTTON 1,1, "Batch", (70,260)-(175,290)
```

```
    BUTTON 2,1, "Interactive", (320,260)-(435,290)
    WHILE DIALOG(0)<>1 : WEND
    filex=DIALOG(1)
    BUTTON CLOSE 1 : BUTTON CLOSE 2
    infile$=FILES$(1,"TEXT")
    IF LEN(infile$)=0 THEN END
    OPEN infile$ FOR INPUT AS #3
RETURN

REM*****OUTPUT MODE*****
OUTBUT:
    CALL TEXTFONT (3) : CALL TEXTSIZE (12) : CALL TEXTFACE (1)
    GOSUB FRAME1
    LOCATE 15,20 : PRINT "                                    "
    LOCATE 15,20 : PRINT "Select an output mode."
    IF bellybutton=3 THEN clipdim=0 ELSE clipdim=1
    BUTTON 1,clipdim, "Clipboard", (70,260)-(170,290)
    BUTTON 2,1, "Screen", (200,260)-(300,290)
    BUTTON 3,1, "Printer", (330,260)-(430,290)
    BEEP : BEEP
    WHILE DIALOG(0)<>1 : WEND
    OUTBUTTON=DIALOG(1)
    CALL TEXTFONT (3) : CALL TEXTSIZE (12) : CALL TEXTFACE (1)
    LOCATE 15,18 : PRINT "                                    "
    LOCATE 15,21 : PRINT "Select model type."
    BUTTON CLOSE 1 : BUTTON CLOSE 2 : BUTTON CLOSE 3
    BEEP : BEEP
    BUTTON 1,1, "Constrained", (70,260)-(175,290)
    BUTTON 2,1, "Un-constrained", (320,260)-(435,290)
    WHILE DIALOG(0)<>1 : WEND
    modtype=DIALOG(1)
    CALL TEXTFONT (3) : CALL TEXTSIZE (12) : CALL TEXTFACE (1)
    LOCATE 15,18 : PRINT "                                    "
    LOCATE 15,21 : PRINT "Turning crank..."
    BUTTON CLOSE 1 : BUTTON CLOSE 2 : MENU RESET
    ON bellybutton GOSUB CLIPIN, KEYIN, FILEIN
    ON modtype GOTO CONSTRAINED,UNCONSTRAINED

REM*****KEYBOARD INPUT*****
KEYIN:
CLS
CALL TEXTFONT(3) : CALL TEXTFACE (0) : CALL TEXTSIZE (12)
LOCATE 1,1 : INPUT; "Number of oxides"; M
LOCATE 1,20 : INPUT; "   Number of phases"; N
LOCATE 2,1 : INPUT; "Model ident."; IDENT$
LOCATE 3,1 : INPUT; "Single subtracted oxide"; KQ$ : IF KQ$<>"" THEN LOCATE 3,27 : INPUT; "Weight %
of single subtracted oxide"; QKQ
LOCATE 5,20 : PRINT "Input Analyses"
REM LOCATE 6,1 : PRINT "Oxide";
FOR j=1 TO N+2 : LOCATE 6,j*8
    IF j<=N THEN PRINT " Phase"; j ELSE IF j=N+1 THEN PRINT " Parent" ELSE PRINT " Daughter"
    LOCATE 6,j*8 : INPUT; "", PHASE$(j)
NEXT
LOCATE 6,1 : PRINT "Oxide"
FOR i=1 TO M
    LOCATE 6+i,1 : INPUT; "", OXIDE$(i)
    IF OXIDE$(i)=KQ$ THEN KQ=i ELSE KQ=0
    FOR j=1 TO N+2 : LOCATE 6+i,j*8+2 : INPUT; "", AN(i,j) : NEXT
NEXT
ON modtype GOTO CONSTRAINED,UNCONSTRAINED

REM*****OPEN CLIPBOARD FOR DATA INPUT FROM MULTIPLAN*****
CLIPIN:
OPEN "CLIP:" FOR INPUT AS #2
    INPUT #1, DUMMY$, DUMMY$, M, DUMMY$, DUMMY$, N
    IF N >3 THEN FOR i=7 TO N+3 : INPUT #1, DUMMY$ : NEXT
    INPUT #1, DUMMY$, IDENT$
    IF N>3 THEN FILL=N+3 ELSE FILL=6
    FOR i=3 TO FILL : INPUT #1, DUMMY$ : NEXT
    INPUT #1, DUMMY$, DUMMY$, KQ : INPUT #1, DUMMY$, QKQ : INPUT #1, DUMMY$
```

```
    IF N>3 THEN FOR i=7 TO N+3 : INPUT #1, DUMMY$ : NEXT
    FOR j= 0 TO N+2 : INPUT #1, PHASE$(j) : NEXT : IF N<3 THEN INPUT #1, DUMMY$
    FOR i=1 TO M
        INPUT #1, OXIDE$(i)
        FOR j=1 TO N+2 : INPUT #1, AN(i,j) : NEXT
        IF N<3 THEN INPUT #1, DUMMY$
    NEXT
CLOSE #2
ON modtype GOTO CONSTRAINED,UNCONSTRAINED

REM*****OPEN A FILE FOR INPUT*****
FILEIN:
    fileopen=1
    marker$=CHR$(9) 'TAB field delimiter
    start=0
    i=0
    j=1
    fline=0
    KQ=0
    kqq=0
    LOCATE 15,20 : PRINT "                                    "
    LOCATE 15,21 : PRINT "Reading file..."
    WHILE NOT EOF(3)
    index=0
    LINE INPUT #3, SEARCH$
    IF SEARCH$="" THEN N=j-3 : RETURN
    begin:
        LONG=LEN(SEARCH$)
        FIRST=INSTR(SEARCH$,marker$)
        IF FIRST=0 THEN REF$=SEARCH$ : GOTO LOOP
        REF$=LEFT$(SEARCH$,FIRST-1) : SEARCH$=MID$(SEARCH$,FIRST+1,LONG)
    LOOP:
        IF start=0 THEN IDENT$=REF$ : PRINT  IDENT$ : start=1 : GOTO nextline ELSE GOSUB ASSIGN :
IF FIRST=0 GOTO nextline ELSE GOTO begin
    ASSIGN:
        IF fline=0 THEN IF kqq=0 THEN KQ$=REF$ : kqq=1 : RETURN ELSE QKQ=VAL(REF$) : fline=1 :
RETURN
        IF fline=1 THEN OXIDE$(i)=REF$ : GOSUB subox : IF FIRST=0 THEN fline=2 : M=i : i=1 : RETURN
ELSE i=i+1 : RETURN
        IF index=0 THEN index=1 : PHASE$(j)=REF$ : RETURN ELSE AN(i,j)=VAL(REF$) : IF FIRST=0
THEN i=1 : j=j+1 : RETURN ELSE i=i+1 : RETURN
        subox:
            IF OXIDE$(i)=KQ$ THEN KQ=i
    RETURN
    nextline:
WEND
N=j-3
RETURN

REM*****BEGIN REAL PROGRAM!!*****
REM***** RECALCULATE ANALYSES TO 100%*****
CONSTRAINED:
FOR j=1 TO N+2
    FOR i=1 TO M : OAN(i,j)=AN(i,j) : NEXT
    SUM=0
     FOR i=1 TO M
        SUM=SUM+AN(i,j)
    NEXT
    SUMTOT(j)=SUM
    IF SUM=0 THEN SUM=1
    FOR i=1 TO M
        AN(i,j)=(AN(i,j)/SUM)*100
        CN(i,j)=AN(i,j)
    NEXT
NEXT

UNCONSTRAINED:
LOCATE 15,20 : PRINT "                                    "
LOCATE 15,21 : PRINT "Calculating values..."
REM*****CALCULATE MASS BALANCE EQUATIONS*****
```

```
IF modtype=1 THEN NORESET
FOR j=1 TO N+2 : FOR i=1 TO M : OAN(i,j)=AN(i,j) : NEXT : NEXT
FOR j=1 TO N+2 : SUM=0 : FOR i=1 TO M : SUM=SUM+AN(i,j) : NEXT : SUMTOT(j)=SUM : NEXT
NORESET:
FOR i=1 TO M
    FOR j=1 TO N+2 : CN(i,j)=AN(i,j) : NEXT
    AN(i,N+1)=AN(i,N+2)-AN(i,N+1)
NEXT
FOR j=1 TO N
    FOR i=1 TO M
        AN(i,j)=(AN(i,j)-AN(i,N+2))/100
    NEXT
NEXT

REM*****COMPUTE NORMAL EQUATIONS FOR LEAST-SQUARES*****
FOR i=1 TO N
    FOR j=1 TO N
        SUM=0
        FOR K=1 TO M
            SUM=SUM+AN(K,i)*AN(K,j)
        NEXT
        BN(i,j)=SUM
    NEXT
NEXT
FOR j=1 TO N
    SUM=0
    FOR i=1 TO M
        SUM=SUM+AN(i,j)*AN(i,N+1)
    NEXT
    FF(j,1)=SUM
NEXT

REM*****SOLVE FOR AMOUNTS OF PHASES WITH MATINV*****
NONE=N+1
LEX=12-N
FOR i=NONE TO 12
    FF(i,1)=1
    FOR j=NONE TO 12
        BN(i,j)=1
    NEXT
NEXT
CALL MATINV (BN(), N, FF())
FOR i=1 TO N
    F(i)=FF(i,1)
NEXT

REM*****CALCULATE RESIDUALS, STAND. ERRORS, SUM OF (RESIDUALS)**2
LOCATE 15,20 : PRINT "                    "
LOCATE 15,21 : PRINT "Calculating values..."
RESQ=0
RES=0
FOR i=1 TO M
    SUM=0
    FOR j=1 TO N
        SUM=SUM+F(j)*AN(i,j)
    NEXT
    YY(i)=SUM
    D(i)=AN(i,N+1)-SUM
    RES=RES+D(i)
    RESQ=RESQ+D(i)*D(i)
NEXT
RN=M-N
FOR i=1 TO N
    STD(i)=BN(i,i)*(RESQ/RN)
    STD(i)=SQR(STD(i))
NEXT

REM*****CALCULATE COMPOSITION OF ADDED OR SUBTRACTED MATERIAL****
FOR i=1 TO M
    SUMN=0
```

```
    SUM=0
    FOR j=1 TO N
        IF F(j)<0 THEN SUMN=SUMN+F(j)*CN(i,j) ELSE SUM=SUM+F(j)*CN(i,j)
    NEXT
    P(i)=SUM
    PN(i)=SUMN
NEXT
SUM=0
SUMN=0
FOR i=1 TO M
    SUM=SUM+P(i)
    SUMN=SUMN+PN(i)
NEXT
IF SUM=0 THEN SUM=1
IF SUMN=0 THEN SUMN=1
FOR i=1 TO M
    P(i)=(P(i)/SUM)*100
    PN(i)=(PN(i)/SUMN)*100
NEXT

REM*****RECALCULATE PHASE AMOUNTS TO 100%*****
SUM=0
SUM1=0
SUM2=0
FOR i=1 TO N
    IF F(i)<0 THEN SUM=SUM+F(i) ELSE SUM1=SUM1+F(i)
    SUM2=SUM2+ABS(F(i))
NEXT
IF SUM=0 THEN SUM=1
IF SUM1=0 THEN SUM1=1
IF SUM2=0 THEN SUM2=1
FOR i=1 TO N
    IF F(i)<0 THEN XN(i)=(F(i)/SUM)*100 : XP(i)=0 ELSE XP(i)=(F(i)/SUM1)*100 : XN(i)=0
    X(i)=(ABS(F(i))/SUM2)*100
NEXT

REM*****CALCULATE MASS OF NEW MAGMA*****
SUM=0
FOR i=1 TO N : SUM=SUM+F(i) : NEXT
TOT=100+SUM

REM***** CALCULATE THE COMPOSITION OF THE ONE PHASE WHICH WILL
REM       EXACTLY GIVE THE DIFFERENCE IN COMPOSITION OF THE TWO
REM       MAGMAS*****
IF KQ=0 OR AN(KQ,N+2)-QKQ=0 THEN GOROUND
    Y(KQ)=QKQ : XSPEC=(AN(KQ,N+1)/(AN(KQ,N+2)-Y(KQ)))*100
    FOR i=1 TO M : Y(i)=(AN(i,N+2)*XSPEC-100*AN(i,N+1))/XSPEC : NEXT

REM*****END OF REAL PROGRAM*****

GOROUND:
IF BUTEST=0 THEN ON OUTBUTTON GOSUB CLIPOUT, SCRNOUT, PRINTOUT
IF fileopen=1 AND NOT EOF(3) GOTO start
IF fileopen=0 THEN dimbut=1 ELSE dimbut=0
WINDOW 1
CLS
CALL TEXTFONT (2) : CALL TEXTFACE (1) : CALL TEXTSIZE (36)
LOCATE 1,3 : PRINT "Make another choice"
CALL TEXTFONT (3) : CALL TEXTSIZE (12)
LOCATE 15,23 : PRINT "Output again?"
    BUTTON 1,dimbut, "Clipboard", (70,260)-(170,290)
    BUTTON 2,dimbut, "Screen", (200,260)-(300,290)
    BUTTON 3,dimbut, "Printer", (330,260)-(430,290)
    BUTTON 4,1, "Take it from the top", (180,100)-(330,130)
    BUTTON 5,1, "Quit", (180,150)-(330,180)
IF OUTBUTTON <>1 THEN GOTO NOMULT
LOCATE 5,4 : PRINT USING "Paste data into Multiplan document as ## rows by 10 columns"; M+N+11
NOMULT:
    WHILE DIALOG(0)<>1 : WEND
    OUTBUTTON=DIALOG(1)
```

```
    BUTTON CLOSE 1 : BUTTON CLOSE 2 : BUTTON CLOSE 3 : BUTTON CLOSE 4 : BUTTON CLOSE 5
    ON OUTBUTTON GOTO CLIPOUT, SCRNOUT, PRINTOUT, TIFTT, OUTAHERE

REM***** OUTPUT ROUTINES*****

CLIPOUT:
BUTEST=1
OPEN "CLIP:" FOR OUTPUT AS #2
    WRITE #1, "Oxide", "Observed", "Calculated", "Observed", "Added", "Subtracted", "Single", DUMMY$,
DUMMY$, DUMMY$
    WRITE #1, DUMMY$, "difference", "difference", "minus", "material", "material", "subtracted", DUMMY$,
DUMMY$, DUMMY$
    WRITE #1, DUMMY$, "Pg-Dg", "Pc-Dc", "calculated", DUMMY$, DUMMY$, "phase", DUMMY$, DUMMY$,
DUMMY$
    FOR i=1 TO M
        WRITE #1, OXIDE$(i), AN(i,N+1), YY(i), D(i), P(i), PN(i), Y(i), DUMMY$, DUMMY$
    NEXT
    WRITE #1, : WRITE #1, "Phase", "Amounts of", "Percent of", "+ phases", "- phases", "Standard",
DUMMY$, DUMMY$, DUMMY$, DUMMY$
    WRITE #1, DUMMY$, "phase per", "phase", "recalculated", "recalculated", "errors", DUMMY$, DUMMY$,
DUMMY$, DUMMY$
    WRITE #1, DUMMY$, "100 initial", DUMMY$, "to 100%", "to 100%", DUMMY$, DUMMY$, DUMMY$,
DUMMY$, DUMMY$
    FOR j=1 TO N
        WRITE #1, PHASE$(j), F(j), X(j), XP(j), XN(j), STD(j), DUMMY$, DUMMY$, DUMMY$
    NEXT
    WRITE #1,
    WRITE #1, "Mass of new magma", DUMMY$, "  Σ  ", " Σ*Σ ", DUMMY$, DUMMY$, DUMMY$,
DUMMY$, DUMMY$
    WRITE #1, "relative to 100 of old", DUMMY$,  DUMMY$, DUMMY$, DUMMY$, DUMMY$, DUMMY$,
DUMMY$, DUMMY$, DUMMY$
    WRITE #1, TOT, DUMMY$, RES, RESQ,  DUMMY$, DUMMY$, DUMMY$, DUMMY$, DUMMY$
CLOSE #2
GOTO GOROUND

PRINTOUT:
BUTEST=1
LOCATE 15,18 : PRINT "                                    "
LOCATE 15,21 : PRINT "Printing output..."
OPEN "LPT1:DIRECT" FOR OUTPUT AS #2 LEN=4000
WIDTH LPRINT 160,10
PRINT #2, ESC$;CHR$(118)          'SET TOP OF FORM
PRINT #2, ESC$;CHR$(81)          'SET CHARACTER SIZE TO 17 CPI
    PRINT #2, "Model ident.  "; IDENT$
    PRINT #2, "Number of oxides is.."; M; "Number of phases is.."; N
    PRINT #2, "              Input analyses"
    PRINT #2, "Oxide ";
    FOR j=1 TO N+2 : PRINT #2, USING "  \     \"; PHASE$(j); : NEXT
    PRINT #2,
    FOR i=1 TO M
        PRINT #2, USING "\    \"; OXIDE$(i);
        FOR j=1 TO N+2 : PRINT #2, USING " ####.##   "; OAN(i,j); : NEXT
        PRINT #2,
    NEXT
    PRINT #2, USING "\    \ "; "Total";
    FOR j=1 TO N+2 : PRINT #2, USING " ####.##  "; SUMTOT(j); : NEXT
    IF modtype=2 THEN GOTO NORECALCP
    PRINT #2, : PRINT #2, : PRINT #2,
    PRINT #2, "              Recalculated analyses"
    PRINT #2, "Oxide ";
    FOR j=1 TO N+2 : PRINT #2, USING "  \     \"; PHASE$(j); : NEXT
    PRINT #2,
    FOR i=1 TO M
        PRINT #2, USING "\    \"; OXIDE$(i);
        FOR j=1 TO N+2 : PRINT #2, USING " ####.##   "; CN(i,j); : NEXT
        PRINT #2,
    NEXT
NORECALCP:
    PRINT #2, : PRINT #2, "                          Results of the calculations"
    PRINT #2, "Oxide      Observed      Calculated      Observed      Added      Subtracted"; : IF KQ<>0
```

```
THEN PRINT #2, "      Single" ELSE PRINT #2,
    PRINT #2, "          difference    difference       minus      material     material"; : IF KQ<>0 THEN PRINT
#2, "     subtracted" ELSE PRINT #2,
    PRINT #2, "          Pg-Dg         Pc-Dc        calculated                              "; : IF KQ<>0 THEN
PRINT #2, "       phase" ELSE PRINT #2,
    FOR i=1 TO M
        PRINT #2, USING "\   \     ###.##       ###.##        ###.##        ###.##        ###.##"; OXIDE$(i);
AN(i,N+1); YY(i); D(i); P(i); PN(i);
        IF KQ<>0 THEN PRINT #2, USING "          ###.##"; Y(i) ELSE PRINT #2,
    NEXT
    PRINT #2,
    PRINT #2, "Phase      Amounts of       Percent of       + phases          - phases          Standard"
    PRINT #2, "          phase per          phase          recalculated      recalculated      errors"
    PRINT #2, "          100 initial                       to 100%           to 100%"
    FOR j=1 TO N
        PRINT #2, USING "\     \   ####.##          ####.##          ####.##          ####.##
####.##"; PHASE$(j); F(j); X(j); XP(j); XN(j); STD(j)
    NEXT
    PRINT #2, USING "Mass of new magma relative to 100 of old... ####.##"; TOT
    PRINT #2, USING "Sum of residuals... ##.######"; RES; : PRINT #2, USING "     Sum of squares of
residuals... ##.######"; RESQ
    REM PRINT #2, CHR$(12)    'SEND FORM FEED
CLOSE #2
GOTO GOROUND

FILEOUT:
BUTEST=1
OUTFILE$=FILES$(0,"Name the outout file:")
OPEN OUTFILE$ FOR OUTPUT AS #2 LEN=4000
    PRINT #2, "Model ident.  "; IDENT$
    PRINT #2, "Number of oxides is.."; M; "Number of phases is.."; N
    PRINT #2, "              Input analyses"
    PRINT #2, "Oxide ";
    FOR j=1 TO N+2 : PRINT #2, USING "  \     \ "; PHASE$(j); : NEXT
    PRINT #2,
    FOR i=1 TO M
        PRINT #2, USING "\    \"; OXIDE$(i);
        FOR j=1 TO N+2 : PRINT #2, USING " ####.##   "; OAN(i,j); : NEXT
        PRINT #2,
    NEXT
    PRINT #2, USING "\    \ "; "Total";
    FOR j=1 TO N+2 : PRINT #2, USING " ####.##  "; SUMTOT(j); : NEXT
    IF modtype=2 THEN GOTO NORECALCF
    PRINT #2, : PRINT #2, : PRINT #2,
    PRINT #2, "              Recalculated analyses"
    PRINT #2, "Oxide ";
    FOR j=1 TO N+2 : PRINT #2, USING "  \     \ "; PHASE$(j); : NEXT
    PRINT #2,
    FOR i=1 TO M
        PRINT #2, USING "\    \"; OXIDE$(i);
        FOR j=1 TO N+2 : PRINT #2, USING " ####.##   "; CN(i,j); : NEXT
        PRINT #2,
    NEXT
NORECALCF:
    PRINT #2, : PRINT #2, "                          Results of the calculations"
    PRINT #2, "Oxide      Observed      Calculated      Observed      Added      Subtracted"; : IF KQ<>0
THEN PRINT #2, "      Single" ELSE PRINT #2,
    PRINT #2, "          difference    difference       minus      material     material"; : IF KQ<>0 THEN PRINT
#2, "     subtracted" ELSE PRINT #2,
    PRINT #2, "          Pg-Dg         Pc-Dc        calculated                              "; : IF KQ<>0 THEN
PRINT #2, "       phase" ELSE PRINT #2,
    FOR i=1 TO M
        PRINT #2, USING "\   \     ###.##       ###.##        ###.##        ###.##        ###.##"; OXIDE$(i);
AN(i,N+1); YY(i); D(i); P(i); PN(i);
        IF KQ<>0 THEN PRINT #2, USING "          ###.##"; Y(i) ELSE PRINT #2,
    NEXT
    PRINT #2,
    PRINT #2, "Phase      Amounts of       Percent of       + phases          - phases          Standard"
    PRINT #2, "          phase per          phase          recalculated      recalculated      errors"
    PRINT #2, "          100 initial                       to 100%           to 100%"
```

```
    FOR j=1 TO N
        PRINT #2, USING "\     \   ####.##          ####.##         ####.##         ####.##
####.##"; PHASE$(j); F(j); X(j); XP(j); XN(j); STD(j)
    NEXT
    PRINT #2, USING "Mass of new magma relative to 100 of old... ####.##"; TOT
    PRINT #2, USING "Sum of residuals... ##.######"; RES; : PRINT #2, USING "     Sum of squares of
residuals... ##.######"; RESQ
    REM PRINT #2, CHR$(12)    'SEND FORM FEED
CLOSE #2
GOTO GOROUND


SCRNOUT:
BUTEST=1
OPEN "SCRN:" FOR OUTPUT AS #2
WINDOW 2, "", (7,27)-(505,332),2
    CLS
    PRINT #2, "Model ident.  "; IDENT$
    PRINT #2, "Number of oxides is.."; M; "Number of phases is.."; N
    LOCATE 3,10 : PRINT #2, "Input analyses"
    LOCATE 4,1 : PRINT #2, "Oxide";
    FOR j=1 TO N+2 : LOCATE 4,j*8 : PRINT #2, LEFT$(PHASE$(j),8); : NEXT
    PRINT #2, : RR=0
    FOR i=1 TO M
        R=i-RR
        LOCATE 4+R,1
        PRINT #2, LEFT$(OXIDE$(i),7)
        FOR j=1 TO N+2
            LOCATE 4+R,j*8 : PRINT #2, USING "###.##"; OAN(i,j);
        NEXT
        IF R=M THEN GOSUB PRTOT
        IF R=M GOTO NEXTFRAME ELSE IF R=17 THEN GOSUB CONTSCRN
    NEXT
PRTOT:
    LOCATE 5+R,1 : PRINT #2,"Total";
    FOR j=1 TO N+2
        LOCATE 5+R,j*8 : PRINT #2, USING "###.##"; SUMTOT(j);
    NEXT : RETURN
NEXTFRAME:
    GOSUB CONTSCRN
    IF modtype=1 THEN GOSUB RECAL
RESULTS:
    CLS
    LOCATE 1,20 : PRINT #2, "Results of the calculations"
    LOCATE 3,1 : PRINT #2, "Oxide" : LOCATE 3,8 : PRINT #2, "Observed"
    LOCATE 3,16 : PRINT #2, "Calculated" : LOCATE 3,25 : PRINT #2, "Observed"
    LOCATE 3,35 : PRINT #2, "Added" : LOCATE 3,43 : PRINT #2, "Subtracted"
    IF KQ<>0 THEN LOCATE 3,54 : PRINT #2, "Single" : ELSE DUMMY=DUMMY
    LOCATE 4,7 : PRINT #2, "difference" : LOCATE 4,16 : PRINT #2, "difference"
    LOCATE 4,26 : PRINT #2, "minus" : LOCATE 4,34 : PRINT #2, "material"
    LOCATE 4,44 : PRINT #2, "material"
    IF KQ<>0 THEN LOCATE 4,53 : PRINT #2, "subtracted" ELSE DUMMY=DUMMY
    LOCATE 5,9 :PRINT #2, "Pg-Dg" : LOCATE 5,18 : PRINT #2, "Pc-Dc"
    LOCATE 5,25 : PRINT #2, "calculated"
    IF KQ<>0 THEN LOCATE 5,54 : PRINT #2, "phase" : ELSE DUMMY=DUMMY
    RR=0
    FOR i=1 TO M
        R=i-RR : LOCATE 5+R,1 : PRINT #2, OXIDE$(i)
        LOCATE 5+R,9 : PRINT #2, USING "###.##"; AN(i,N+1);
        LOCATE 5+R,18 : PRINT #2, USING "###.##"; YY(i);
        LOCATE 5+R,26 : PRINT #2, USING "###.##"; D(i);
        LOCATE 5+R,35 : PRINT #2, USING "###.##"; P(i);
        LOCATE 5+R,45 : PRINT #2, USING "###.##"; PN(i);
        IF KQ<>0 THEN LOCATE 5+R,54 : PRINT #2, USING "###.##"; Y(i); ELSE DUMMY=DUMMY
        IF R=M GOTO RESULTS1 ELSE IF R=17 THEN GOSUB CONTSCRN
    NEXT
RESULTS1:
    GOSUB CONTSCRN
    CLS
    LOCATE 2,1 :PRINT #2, "Phase" : LOCATE 2,8 : PRINT #2, "Amounts of"
```

```
    LOCATE 2,20 : PRINT #2, "Percent of" : LOCATE 2,32 : PRINT #2, "+ phases"
    LOCATE 2,43 : PRINT #2, "- phases" : LOCATE 2,53 : PRINT #2, "Standard"
    LOCATE 3,9 : PRINT #2, "phase per" : LOCATE 3,21 : PRINT #2, "phase"
    LOCATE 3,31 : PRINT #2, "recalculated" : LOCATE 3,42 : PRINT #2, "recalculated"
    LOCATE 3,54 : PRINT #2, "errors"
    LOCATE 4,8 : PRINT #2, "100 initial" : LOCATE 4,33 : PRINT #2, "to 100%"
    LOCATE 4,44 : PRINT #2, "to 100%"
    RR=0
    FOR j=1 TO N
        R=j-RR
        LOCATE 4+R,1 : PRINT #2, LEFT$(PHASE$(j),8)
        LOCATE 4+R,11 : PRINT #2, USING "###.##"; F(j)
        LOCATE 4+R,22 : PRINT #2, USING "###.##"; X(j)
        LOCATE 4+R,33 : PRINT #2, USING "###.##"; XP(j)
        LOCATE 4+R,44 : PRINT #2, USING "###.##"; XN(j)
        LOCATE 4+R,55 : PRINT #2, USING "##.##"; STD(j)
        IF R=N THEN GOTO RESD ELSE DUMMY=DUMMY
        IF R=17 THEN GOSUB CONTSCRN
    NEXT
RESD:
    IF R=N THEN RR=R+6 ELSE CLS : RR=2
    IF R=17 THEN GOSUB CONTSCRN
    LOCATE RR,2 : PRINT #2, USING "Mass of new magma relative to 100 of old is... ###.##"; TOT
    LOCATE RR+2,2
    PRINT#2, USING "Sum of residuals.. ##.######"; RES; : PRINT #2, USING "      Sum of squares of
residuals.. ##.######"; RESQ
    GOSUB QUITSCRN
CLOSE #2
GOTO GOROUND
RECAL:
    CLS
    LOCATE 2,10 : PRINT #2, "Recalculated analyses"
    LOCATE 4,1 : PRINT #2, "Oxide";
    FOR j=1 TO N+2 : LOCATE 4,j*8 : PRINT #2, LEFT$(PHASE$(j),8); : NEXT
    PRINT #2, : RR=0
    FOR i=1 TO M
        R=i-RR
        LOCATE 4+R,1
        PRINT #2, LEFT$(OXIDE$(i),7)
        FOR j=1 TO N+2 : LOCATE 4+R,j*8 : PRINT #2, USING "###.##"; CN(i,j); : NEXT
        PRINT #2,
        IF R=M OR R=17 THEN GOSUB CONTSCRN
        IF R=M GOTO RESULTS
    NEXT : RETURN
CONTSCRN:
    BUTTON 1,1, "Continue", (175,275)-(315,305), 1
    WHILE DIALOG(0)<>1 : WEND : RR=17 : RETURN
QUITSCRN:
    BUTTON 1,1, "Close", (175,275)-(315,305), 1
    WHILE DIALOG(0)<>1 : WEND
CLOSE #2
GOTO GOROUND

REM*****MENU SUBROUTINES

MENUCHK:
    MENUNUMBER=MENU(0) : IF MENUNUMBER <>10 THEN RETURN
    MENUITEM=MENU(1)
    ON MENUITEM GOSUB REFER, HELP, IO
    GOTO OPENFRAME

REFER:
FILENUM=1
WINDOW 3, "I/O",(10,30)-(500,290), 3
WHILE FILENUM<=1
    FILENAME$="DD 20:BASIC:MAGMA MODELING:XLFRAC Help:XLFRAC.REFER"
    FILENAME$=FILENAME$+STR$(FILENUM)
    OPEN FILENAME$ FOR INPUT AS #4
    Image$=INPUT$(LOF(4),4)
    CLS
```

```
    PICTURE (2,5), Image$
    WHILE MOUSE(0)<>1 : WEND : FILENUM=FILENUM+1
    CLOSE #4
WEND
WINDOW CLOSE 3
RETURN


HELP:
FILENUM=1
WINDOW 3, "I/O",(10,30)-(500,290), 3
WHILE FILENUM<=3
    FILENAME$="DD 20:BASIC:MAGMA MODELING:XLFRAC Help:XLFRAC.HELP"
    FILENAME$=FILENAME$+STR$(FILENUM)
    OPEN FILENAME$ FOR INPUT AS #4
    Image$=INPUT$(LOF(4),4)
    CLS
    PICTURE (2,5), Image$
    WHILE MOUSE(0)<>1 : WEND : FILENUM=FILENUM+1
    CLOSE #4
WEND
WINDOW CLOSE 3
RETURN

IO:
FILENUM=1
WINDOW 3, "I/O",(10,30)-(500,290), 3
WHILE FILENUM<=3
    FILENAME$="DD 20:BASIC:MAGMA MODELING:XLFRAC Help:XLFRAC.I/O"
    FILENAME$=FILENAME$+STR$(FILENUM)
    OPEN FILENAME$ FOR INPUT AS #4
    Image$=INPUT$(LOF(4),4)
    CLS
    PICTURE (2,5), Image$
    WHILE MOUSE(0)<>1 : WEND : FILENUM=FILENUM+1
    CLOSE #4
WEND
WINDOW CLOSE 3
RETURN

REM*****PROGRAM STOP*****
OUTAHERE:
CLS : CALL TEXTFONT (2) : CALL TEXTSIZE (36) : CALL TEXTFACE (1)
LOCATE 5,5 : PRINT "Adios amigo!"
RESET
END

REM*****MATRIX INVERSION SUBPROGRAM*****
SUB MATINV(A(),N,B()) STATIC
LOCATE 15,20 : PRINT "                                    "
LOCATE 15,21 : PRINT "Inverting matrix..."
DETERM=1 : M=1
FOR j=1 TO N : IPIVOT(j)=0 : NEXT
FOR i=1 TO N
    MATS=0
    FOR j=1 TO N
        IF IPIVOT(j)-1=0 THEN 10
        FOR K=1 TO N
            IF IPIVOT (K)-1<0 THEN IF ABS(MATS)-ABS(A(j,K))<0 THEN ROW=j : COL=K : MATS=A(j,K) :
GOTO 5 ELSE GOTO 5 ELSE IF IPIVOT(K)-1=0 THEN GOTO 5 ELSE GOTO 100
5
        NEXT
10
    NEXT
    IPIVOT(COL)=IPIVOT(COL)+1
    IF ROW-COL=0 THEN GOTO 26
    DETERM=-DETERM
    FOR L=1 TO N
        MATS=A(ROW,L)
        A(ROW,L)=A(COL,L)
```

```
        A(COL,L)=MATS
    NEXT
    IF M<=0 THEN GOTO 26
    FOR L=1 TO M
        MATS=B(ROW,L)
        B(ROW,L)=B(COL,L)
        B(COL,L)=MATS
    NEXT
26
    index(i,1)=ROW
    index(i,2)=COL
    PIVOT(i)=A(COL,COL)
    C=DETERM*PIVOT(i)
    DETERM=C
    A(COL,COL)=1
    FOR L=1 TO N
        C=A(COL,L)/PIVOT(i)
        A(COL,L)=C
    NEXT
    IF M=0 GOTO 38
    FOR L=1 TO M
        C=B(COL,L)/PIVOT(i)
        B(COL,L)=C
    NEXT
38
    FOR L1=1 TO N
        IF L1-COL=0 THEN GOTO 20
        T=A(L1,COL)
        A(L1,COL)=0
        FOR L=1 TO N : A(L1,L)=A(L1,L)-A(COL,L)*T : NEXT
        IF M<=0 THEN GOTO 20
        FOR L=1 TO M : B(L1,L)=B(L1,L)-B(COL,L)*T : NEXT
20
    NEXT
NEXT
FOR i=1 TO N
    L=N+1-i
    IF index(L,1)-index(L,2)=0 THEN GOTO 50
    ROW=index(L,1)
    COL=index(L,2)
    FOR K=1 TO N
        MATS=A(K,ROW)
        A(K,ROW)=A(K,COL)
        A(K,COL)=MATS
    NEXT
50
NEXT
100
END SUB
```

TOOLS - A SET OF SMALL USEFUL EXCEL™ MACROS.

Environment: Excel™, version 1.05 or greater
Installed resources: n.a.

These small macros were written to automate some of the repetitive operations on worksheets that were required from time to time. All of them should be self explanatory.

Cross reference of Excel file Tools

Names with cell references

R95C1	Append.String
R87C1	Copy.To.Text
R72C1	Empty.Fills

R57C1	Fill.Empties
R109C1	Find.Duplicates
R24C1	LOOP
R43C1	Plot.It.Cols
R50C1	Plot.It.Rows
R2C1	Tranpose.It

Names with values.

"e"	AppString
8	Cells
1166	changed
8	Count
'::::Excel:Databases:WR Anal. dB'!R5C2:R143C67	Crange
0	dupe
31086.023680556	finish
"12 seconds ,9"	howlong
'::::Scrap:MinIndex'!R11C3	Orange
31086.023657407	start
"Atestburp"	String
'::::Scrap:MinIndex'!R11C8	tcol
1	Tcols
6	tees
'::::Scrap:MinIndex'!R1C1:R6C1	Trange
'::::Scrap:MinIndex'!R6C1	trow
6	Trows

Cells with formulas.

R3C1	SET.NAME("Trange",INPUT("Select a range to transpose:",8,"Input Range"))
R4C1	IF(NOT(Trange),RETURN())
R5C1	SET.NAME("Orange",INPUT("Select upper left corner cell of output range:",8,"Output Range"))
R6C1	SET.NAME("Tcols",COLUMNS(Trange))
R7C1	SET.NAME("Trows",ROWS(Trange))
R8C1	ECHO(FALSE)
R9C1	SET.NAME("start",NOW())
R10C1	FORMULA.GOTO(Tools!Trange)
R11C1	SELECT(ACTIVE.CELL():OFFSET(ACTIVE.CELL(),0,Tcols-1))
R13C1	FORMULA.GOTO(Tools!Orange)
R14C1	SELECT(ACTIVE.CELL():OFFSET(Orange,Tcols-1,0))
R15C1	FORMULA.ARRAY("=TRANSPOSE('Tools'!trow)")
R16C1	COPY()
R17C1	PASTE.SPECIAL(2)
R18C1	PASTE.SPECIAL(3)
R19C1	SET.NAME("tcol",SELECTION())
R20C1	SET.NAME("tees",1)
R21C1	SET.NAME("finish",NOW())
R22C1	IF(SECOND(finish-start)*Trows<60,SET.NAME("howlong",TEXT((SECOND(finish-start))*Trows,"#")&" seconds ,9"),SET.NAME("howlong",TEXT((SECOND(finish-start))*Trows/60,"#")&" minutes ,9"))
R23C1	MESSAGE(TRUE,"This will take about "&howlong)
R25C1	IF(Trows-tees=0,GOTO(R[+13]C))
R26C1	SET.NAME("tees",tees+1)
R27C1	FORMULA.GOTO(Tools!trow)
R28C1	SELECT(OFFSET(SELECTION(),1,0))
R29C1	SET.NAME("trow",SELECTION())
R30C1	FORMULA.GOTO(Tools!tcol)
R31C1	SELECT(OFFSET(SELECTION(),0,1))
R32C1	FORMULA.ARRAY("=TRANSPOSE('Tools'!trow)")
R33C1	COPY()
R34C1	PASTE.SPECIAL(2)
R35C1	PASTE.SPECIAL(3)
R36C1	SET.NAME("tcol",SELECTION())
R37C1	GOTO(LOOP)
R38C1	MESSAGE(FALSE)
R39C1	CANCEL.COPY()
R40C1	BEEP()
R41C1	RETURN()
R44C1	COPY()
R45C1	NEW(2)

R46C1	PASTE.SPECIAL(2,TRUE,TRUE)
R47C1	GALLERY.SCATTER(1)
R48C1	RETURN()
R51C1	COPY()
R52C1	NEW(2)
R53C1	PASTE.SPECIAL(1,TRUE,TRUE)
R54C1	GALLERY.SCATTER(1)
R55C1	RETURN()
R58C1	ECHO(FALSE)
R59C1	SET.NAME("changed",0)
R60C1	SET.NAME("Crange",SELECTION())
R61C1	INPUT("Enter the character(s) to fill null cells with:",2,"Fill character")
R62C1	IF(NOT(R[-1]C),GOTO(R[+8]C))
R63C1	MESSAGE(TRUE,changed&" insertions of "&R[-2]C&" ,9")
R64C1	IF(FORMULA.FIND("",1,1,1),GOTO(R[+1]C),GOTO(R[+5]C))
R65C1	FORMULA(R[-4]C)
R66C1	SET.NAME("changed",changed+1)
R67C1	GOTO(R[-4]C)
R68C1	DELETE.NAME("changed")
R69C1	MESSAGE(FALSE)
R70C1	RETURN()
R73C1	ECHO(FALSE)
R74C1	SET.NAME("changed",0)
R75C1	SET.NAME("Crange",SELECTION())
R76C1	INPUT("Enter the character(s) to replace with null cells:",2,"Search character")
R77C1	IF(NOT(R[-1]C),GOTO(R[+8]C))
R78C1	MESSAGE(TRUE,changed&" instances of "&R[-2]C&" changed ,9")
R79C1	IF(FORMULA.FIND(R[-3]C,1,1,1),GOTO(R[+1]C),GOTO(R[+4]C))
R80C1	FORMULA("")
R81C1	SET.NAME("changed",changed+1)
R82C1	GOTO(R[-4]C)
R83C1	MESSAGE(FALSE)
R84C1	DELETE.NAME("changed")
R85C1	RETURN()
R88C1	COPY()
R89C1	NEW(1)
R90C1	PASTE.SPECIAL(3)
R91C1	SAVE.AS?("?.txt",3)
R92C1	CLOSE()
R93C1	RETURN()
R96C1	ECHO(FALSE)
R97C1	SET.NAME("AppString",INPUT("Enter append string:",2))
R98C1	ALERT("Prefix (OK) or suffix (Cancel)? asks Cacaphonix!",1)
R99C1	SET.NAME("Cells",COLUMNS(SELECTION())*ROWS(SELECTION()))
R100C1	SET.NAME("Count",0)
R101C1	MESSAGE(TRUE,"At cell "&Count+1&" of "&Cells)
R102C1	IF(R[-4]C,FORMULA(AppString&DEREF(ACTIVE.CELL())),FORMULA(DEREF(ACTIVE.CELL())&AppString))
R103C1	SELECT(,"R[1]C")
R104C1	SET.NAME("Count",Count+1)
R105C1	IF(Count=Cells,GOTO(R[+1]C),GOTO(R[-4]C))
R106C1	MESSAGE(FALSE)
R107C1	RETURN()
R112C1	ECHO(FALSE)
R115C1	SET.NAME("dupe",DEREF(SELECTION()))
R116C1	SELECT(OFFSET(SELECTION(),1,0))
R117C1	IF(SELECTION()<>dupe,GOTO(R[-2]C))
R118C1	BEEP()
R119C1	SELECT(SELECTION():OFFSET(SELECTION(),-1,0))
R120C1	BEEP()
R121C1	HALT()

Values of cells.

R1C1	"All routines on this sheet are *9H.R. Ballard, 11/88."
R2C1	"Tranpose.It"
R2C2	"by H.R. Ballard"
R3C1	TRUE
R3C2	"This macro takes a user defined selection and"
R4C1	FALSE

```
R4C2        "transposes (swaps rows for columns) it to"
R5C1        TRUE
R5C2        "another user defined area. When the input dialog"
R6C1        TRUE
R6C2        "window appears, make a selection by either"
R7C1        TRUE
R7C2        "entering a range or using the mouse to select a"
R8C1        TRUE
R8C2        "range. The output range is defined by a single cell"
R9C1        TRUE
R9C2        "which marks the upper left hand corner of what"
R10C1       TRUE
R10C2       "will become the tranposed range."
R11C1       TRUE
R12C1       TRUE
R13C1       TRUE
R14C1       TRUE
R15C1       TRUE
R16C1       TRUE
R17C1       TRUE
R18C1       TRUE
R19C1       TRUE
R20C1       TRUE
R21C1       TRUE
R22C1       TRUE
R23C1       TRUE
R24C1       "LOOP"
R25C1       TRUE
R26C1       TRUE
R27C1       TRUE
R28C1       TRUE
R29C1       TRUE
R30C1       TRUE
R31C1       TRUE
R32C1       TRUE
R33C1       TRUE
R34C1       TRUE
R35C1       TRUE
R36C1       TRUE
R37C1       TRUE
R38C1       TRUE
R39C1       TRUE
R40C1       TRUE
R41C1       TRUE
R42C1       "*********************************************************"
R43C1       "Plot.It.Cols"
R44C1       TRUE
R44C2       "Plots a selected row-ordered range on a new scatter"
R45C1       TRUE
R45C2       "chart."
R46C1       TRUE
R47C1       TRUE
R48C1       TRUE
R49C1       "*********************************************************"
R50C1       "Plot.It.Rows"
R51C1       TRUE
R51C2       "Plots a selected column-ordered range on a new scatter"
R52C1       TRUE
R52C2       "chart."
R53C1       FALSE
R54C1       TRUE
R55C1       TRUE
R56C1       "*********************************************************"
R57C1       "Fill.Empties"
R58C1       TRUE
R58C2       "Fills empty cells in the current rectangular selection or"
R59C1       TRUE
R59C2       " worksheet with a character entered by the user."
R60C1       TRUE
R61C1       " -7"
```

R62C1	#VALUE!
R63C1	TRUE
R64C1	TRUE
R65C1	TRUE
R66C1	TRUE
R67C1	TRUE
R68C1	FALSE
R69C1	TRUE
R70C1	TRUE
R71C1	"**********"
R72C1	"Empty.Fills"
R73C1	TRUE
R73C2	"Empties cells in the current rectangular selection or"
R74C1	TRUE
R74C2	"worksheet filled with the character(s) entered by the"
R75C1	TRUE
R75C2	"user."
R76C1	FALSE
R77C1	#VALUE!
R78C1	TRUE
R79C1	TRUE
R80C1	TRUE
R81C1	TRUE
R82C1	TRUE
R83C1	TRUE
R84C1	TRUE
R85C1	TRUE
R86C1	"**********"
R87C1	"Copy.To.Text"
R88C1	TRUE
R88C2	"Copies a the current selection to a new worksheet to be"
R89C1	TRUE
R89C2	"Saved As Text for export."
R90C1	TRUE
R91C1	FALSE
R92C1	FALSE
R93C1	TRUE
R94C1	"**********"
R95C1	"Append.String"
R96C1	TRUE
R96C2	"Appends a user input string to each element of a"
R97C1	TRUE
R97C2	"previously defined selection."
R98C1	FALSE
R99C1	TRUE
R100C1	TRUE
R101C1	TRUE
R102C1	TRUE
R103C1	TRUE
R104C1	TRUE
R105C1	TRUE
R106C1	TRUE
R107C1	TRUE
R108C1	"**********"
R109C1	"Find.Duplicates"
R110C1	"INPUT("Select starting cell.",8,"Find.Duplicates")"
R110C2	"Progressively looks downward in a column from the"
R111C1	"IF(NOT(A110),HALT())"
R111C2	"initial active cell comparing adjacent cells. Beeps and"
R112C1	TRUE
R112C2	"stops with the cell selected when a duplicate is found."
R113C1	"SET.NAME("dupe",SELECTION())"
R114C1	"SELECT(dupe)"
R115C1	TRUE
R116C1	TRUE
R117C1	FALSE
R118C1	TRUE
R119C1	TRUE
R120C1	TRUE
R121C1	TRUE

PHASE ENTRY - AN AUTOMATED DATA ENTRY FORM/DATABASE GENERATOR FOR MICROPROBE PHASE DATA.

Environment: Excel™, version 1.05 or greater
Installed resources: n.a.

Excel™'s database capabilities are quite powerful and can be used to great benefit for data storage, retrieval and analysis, but often all the fields cannot be observed on-screen simultaneously. These work- and macro-sheets provide a single screen entry form for microprobe data which is linked to an intermediate data file of the same construction as the database used for this thesis. The entry form provides a set of cells to input the appropriate information then on command calculates the mineral formula and enters all the data into the intermediate database. Options are available for calculation of water and ferric content by the method of Finger (1972).A macro to append the data of the intermediate database to a larger database file is also included.

The sheets were updated to take advantage of Excel™ version 1.5's programmable menus and dialog boxes, but there are still a couple of small cosmetic bugs to be worked out. The macro sheet (*Phase.Enter) is auto-executable and will open the entry form/calculation sheet (*PhaseEnter) and ask the user where to put the intermediate data.

Cross reference of Excel file *Phase.Enter

Names with cell references

R54C1	Append.data
R37C8	auto_close
R1C1	auto_open
R41C8	CloseDataFile
R3C3:R10C9	DBDT_1
R13C3:R18C9	DBDT_2
R14C8	DBDT_2_Txt
R29C10	Debug_Break
R13C1	Enter.Data
R27C8	ExitToExcel
R26C8	ExitToFinder
R44C2	FileName
R20C8	MenuNumber
R19C8	Menu_Bar_1
R3C10:R10C12	Menu_Def_1
R13C10:R18C12	Menu_Def_2
R33C2	NewFile
R28C2	OldFile
R45C2	Present
R62C8	Restart
R5C1	RestartHere
R3C1	RestartwForm
R57C8	SaveData
R19C10	SelectForm
R26C10	ShowD
R23C10	ShowE
R1C1	Start.Up

Names with values.

{"*Phase.Enter","31022.081643519","*PhaseEntry"}	documents
0	loop
0	Ox
0	Oxides

'::::::Excel:Phases Entry:Interim data file'!R2C1:R2C48Record

#REF!	Scrap
TRUE	Started

Cells with formulas.

R2C1	ECHO(FALSE)
R4C1	OPEN("*PhaseEntry")
R4C11	CloseDataFile
R5C11	SaveData
R6C1	Menu_Bar_1()
R6C11	Restart
R7C1	SET.VALUE(R[-3]C[+8],1)
R7C11	Append.data
R8C1	SET.VALUE(FileName,FALSE)
R8C11	Debug_Break
R9C1	DIALOG.BOX(DBDT_1)
R9C11	ExitToExcel
R10C1	IF(NOT(R[-1]C),HALT())
R10C11	ExitToFinder
R11C1	IF(R[-7]C[+8]=1,NewFile(),OldFile())
R12C1	IF(NOT(R[-1]C),HALT())
R14C1	ECHO(FALSE)
R14C11	Enter.Data
R15C1	CALCULATION(1)
R15C11	SelectForm
R16C1	IF('*PhaseEntry'!n<=1,GOTO(R[+10]C))
R17C1	IF(loop>=1,GOTO(R[+4]C),)
R17C11	ShowE
R18C11	ShowD
R19C1	SET.NAME("loop",1)
R20C1	GOTO(R[+20]C)
R20C8	ADD.BAR()
R20C10	ACTIVATE("*PhaseEntry")
R21C8	ADD.MENU(R[-1]C,Menu_Def_1)
R21C10	SELECT('*PhaseEntry'!Entry)
R22C1	SET.NAME("loop",loop+1)
R22C8	ADD.MENU(R[-2]C,Menu_Def_2)
R22C10	RETURN()
R23C1	IF(loop='*PhaseEntry'!n,GOTO(R[+1]C),GOTO(R[+17]C))
R23C8	SHOW.BAR(R[-3]C)
R24C8	RETURN()
R24C10	ACTIVATE("*PhaseEntry")
R25C1	GOTO(R[+2]C)
R25C10	RETURN()
R26C8	TRUE
R27C1	FORMULA.GOTO('*PhaseEntry'!Oxarray)
R27C10	ACTIVATE(FileName)
R28C1	FORMULA.ARRAY(GET.NAME("Oxides"))
R28C8	SET.VALUE(ExitToFinder,FALSE)
R28C10	RETURN()
R29C1	FORMULA.GOTO('*PhaseEntry'!OxideFactor)
R29C2	OPEN?()
R30C1	SORT(1,'*PhaseEntry'!R4C31,2)
R30C2	IF(NOT(R[-1]C),HALT())
R30C8	CloseDataFile()
R30C10	SHOW.BAR(1)
R31C1	FORMULA.GOTO('*PhaseEntry'!Record)
R31C2	ALERT("Make sure the name Record is defined and properly located!",2)
R31C8	INDEX(documents,1,2)
R31C10	HALT()
R32C1	COPY()
R32C2	FileName()
R32C8	IF(ISERROR(R[-1]C),GOTO(R[+3]C))
R33C1	ACTIVATE(R[+11]C[+1])
R33C8	ACTIVATE("*PhaseEntry")
R34C1	FORMULA.GOTO(!Record)
R34C2	NEW(1)
R34C8	CLOSE(FALSE)
R35C1	PASTE.SPECIAL(4,1)

```
R35C2     FORMULA.GOTO("*PhaseEntry'!Fields)
R35C8     ALERT("Click close box of *Phase.Enter to return to normal menus.",2)
R36C1     PASTE.SPECIAL(3,1)
R36C2     COPY()
R36C8     HALT()
R37C1     SELECT(OFFSET(SELECTION(),1,0))
R37C2     ACTIVATE.NEXT()
R38C1     DEFINE.NAME("Record")
R38C2     PASTE.SPECIAL(3)
R38C8     IF(ExitToFinder,QUIT(),SET.VALUE(ExitToFinder,TRUE))
R39C1     CALCULATION(3)
R39C2     FONT("Geneva",9)
R39C8     SHOW.BAR(1)
R40C1     FORMULA.GOTO("*PhaseEntry'!clz)
R40C2     STYLE(TRUE,FALSE)
R40C8     HALT()
R41C1     CLEAR(3)
R41C2     SELECT(OFFSET(SELECTION(),1,0))
R42C1     IF(loop>=!n,GOTO(R[+5]C),IF(loop=0,GOTO(R[+5]C),GOTO(R[+2]C)))
R42C2     DEFINE.NAME("Record",SELECTION())
R43C1     SELECT("*PhaseEntry'!Marker)
R43C2     SAVE.AS?(NOW(),1)
R43C8     INDEX(documents,1,2)
R44C1     SELECT("*PhaseEntry'!clz,"*PhaseEntry'!R7C5)
R44C2     GET.WINDOW(1)
R44C8     IF(ISERROR(R[-1]C),RETURN(),IF(R[-1]C<>FileName,RETURN()))
R45C1     RETURN()
R45C8     SET.VALUE(R[-31]C[+1],1)
R46C1     CALCULATION(3)
R46C2     SET.NAME("loop",0)
R46C8     SET.VALUE(DBDT_2_Txt,"Save changes to data file?")
R47C1     SET.NAME("loop",0)
R47C2     SET.NAME("Ox",0)
R47C8     DIALOG.BOX(DBDT_2)
R48C1     SET.NAME("Ox",0)
R48C2     SET.NAME("Oxides",0)
R48C8     IF(NOT(R[-1]C),HALT())
R49C1     SET.NAME("Oxides",0)
R49C2     ACTIVATE("*PhaseEntry")
R49C8     ACTIVATE(FileName)
R50C1     ACTIVATE("*PhaseEntry")
R50C2     SELECT("*PhaseEntry'!Marker)
R50C8     IF(R[-36]C[+1]=1,TRUE,FALSE)
R51C1     SELECT("*PhaseEntry'!Marker)
R51C2     SELECT("*PhaseEntry'!Entry,"*PhaseEntry'!Sample_Id.)
R51C8     CLOSE(R[-1]C)
R52C1     SELECT("*PhaseEntry'!Entry,"*PhaseEntry'!Phase)
R52C2     HALT()
R52C8     ENABLE.COMMAND(MenuNumber,"File","Close data file ,9",FALSE)
R53C1     RETURN()
R53C8     ENABLE.COMMAND(MenuNumber,"File",2,FALSE)
R54C8     ENABLE.COMMAND(MenuNumber,"Entry",1,FALSE)
R55C1     ALERT("Select the database file!",3)
R55C8     ENABLE.COMMAND(MenuNumber,"Entry",5,FALSE)
R56C1     OPEN?()
R56C8     RETURN()
R57C1     GET.WINDOW(1)
R58C1     IF(NOT(R[-2]C),HALT())
R58C8     ACTIVATE(FileName)
R59C1     ALERT("Select an interim data file!",3)
R59C8     SAVE()
R60C1     OPEN?()
R60C8     ACTIVATE("*PhaseEntry")
R61C1     IF(NOT(R[-1]C),HALT())
R61C8     RETURN()
R62C1     GET.WINDOW(1)
R63C1     FORMULA.GOTO(!Record)
R63C8     CloseDataFile()
R64C1     SELECT(OFFSET(!Record,-1,0):!R2C1)
R64C8     INDEX(documents,1,1)
```

R65C1	COPY()
R65C8	IF(ISERROR(R[-1]C),GOTO(RestartwForm),GOTO(RestartHere))
R66C1	ACTIVATE(R[-9]C)
R67C1	FORMULA.GOTO(lDatabase)
R68C1	SELECT(OFFSET(ACTIVE.CELL(),ROWS(SELECTION()),0))
R69C1	PASTE.SPECIAL(3)
R70C1	FORMULA.GOTO(SELECTION():lDatabase)
R71C1	SET.DATABASE()
R72C1	FORMULA.GOTO(OFFSET(SELECTION(),1,0) SELECTION())
R73C1	CLOSE(TRUE)
R74C1	SET.VALUE(DBDT_2_Txt,"Delete data file "&DEREF(R[-12]C)&"?")
R75C1	SET.VALUE(R[-61]C[+8],2)
R76C1	DIALOG.BOX(DBDT_2)
R77C1	CLOSE(FALSE)
R78C1	IF(AND(R[-2]C=4,R[-64]C[+8]=1),FILE.DELETE(R[-16]C))
R79C1	RETURN()

Values of cells.

R1C1	"Start.Up"
R1C2	" *9 H.R. Ballard, 11/88."
R1C3	"Dialog Box Definition Table 1"
R1C10	"Menu_Def_1"
R2C1	TRUE
R2C2	"Initialises and opens"
R2C3	"Item #"
R2C4	"X Pos."
R2C5	"Y Pos."
R2C6	"Height"
R2C7	"Width"
R2C8	"Text"
R2C9	"Init/Result"
R2C10	"Menu/Items"
R2C11	"Execute"
R2C12	"Key"
R3C1	"RestartwForm"
R3C2	"worksheets for Enter.Data."
R3C4	100
R3C5	58
R3C6	283
R3C7	165
R3C10	"File"
R4C1	#N/A
R4C3	11
R4C4	50
R4C5	47
R4C8	"Enter into ,9"
R4C9	1
R4C10	"Close data file ,9"
R4C11	"CloseDataFile"
R4C12	"C"
R5C1	"RestartHere"
R5C3	12
R5C4	61
R5C5	68
R5C8	"A new data file"
R5C10	"Save data file"
R5C11	"SaveData"
R5C12	"S"
R6C1	#N/A
R6C3	12
R6C4	61
R6C5	88
R6C8	"An existing data file"
R6C10	"Restart ,9"
R6C11	"Restart"
R6C12	"R"
R7C1	TRUE
R7C3	1
R7C4	182
R7C5	133

R7C6	64
R7C8	"OK"
R7C10	"Append database ,9"
R7C11	"Append.data"
R7C12	"A"
R8C1	TRUE
R8C3	2
R8C4	37
R8C5	131
R8C6	64
R8C8	"Cancel"
R8C10	"-"
R8C11	"Debug_Break"
R9C1	4
R9C3	5
R9C4	54
R9C5	5
R9C8	"Welcome to Phase Entry"
R9C10	"Quit to Excel ,9"
R9C11	"ExitToExcel"
R9C12	"E"
R10C1	FALSE
R10C3	5
R10C4	89
R10C5	22
R10C8	"by H.R. Ballard"
R10C10	"Quit to Finder ,9"
R10C11	"ExitToFinder"
R10C12	"Q"
R11C1	FALSE
R11C3	"Dialog Box Definition Table 2"
R11C10	"Menu_Def_2"
R12C1	FALSE
R12C3	"Item #"
R12C4	"X Pos."
R12C5	"Y Pos."
R12C6	"Height"
R12C7	"Width"
R12C8	"Text"
R12C9	"Init/Result"
R12C10	"Menu/Items"
R12C11	"Execute"
R12C12	"Key"
R13C1	"Enter.Data"
R13C4	99
R13C5	55
R13C6	269
R13C7	124
R13C10	"Entry"
R14C1	TRUE
R14C2	"Takes data from"
R14C3	11
R14C4	30
R14C5	11
R14C6	207
R14C7	57
R14C8	"Save changes to data file?"
R14C9	2
R14C10	"Enter record"
R14C11	"Enter.Data"
R15C1	TRUE
R15C2	""PhaseEntry, calculates"
R15C3	12
R15C4	59
R15C5	35
R15C8	"Yes"
R15C10	"Select Form"
R15C11	"SelectForm"
R15C12	"F"
R16C1	TRUE

R16C2	"formula, iron ratio and"
R16C3	12
R16C4	154
R16C5	35
R16C8	"No"
R16C10	"-"
R17C1	TRUE
R17C2	"averages analyses as"
R17C3	1
R17C4	167
R17C5	89
R17C6	64
R17C8	"OK"
R17C10	"Show entry window"
R17C11	"ShowE"
R17C12	1
R18C1	TRUE
R18C2	"required then places the"
R18C3	2
R18C4	30
R18C5	88
R18C6	64
R18C8	"Cancel"
R18C10	"Show data window"
R18C11	"ShowD"
R18C12	2
R19C1	TRUE
R19C2	"data into an intermediate"
R19C8	"Menu_Bar_1"
R19C10	"SelectForm"
R20C1	TRUE
R20C2	"worksheet which can be"
R20C8	7
R20C10	TRUE
R21C1	TRUE
R21C2	"appended to the main"
R21C8	1
R21C10	TRUE
R22C1	TRUE
R22C2	"database with the"
R22C8	2
R22C10	TRUE
R23C1	TRUE
R23C2	"Append.data macro."
R23C8	TRUE
R23C10	"ShowE"
R24C1	TRUE
R24C8	TRUE
R24C10	TRUE
R25C1	TRUE
R25C8	"ExitToFinder"
R25C10	TRUE
R26C1	TRUE
R26C8	TRUE
R26C10	"ShowD"
R27C1	TRUE
R27C2	"Subroutines"
R27C8	"ExitToExcel"
R27C10	TRUE
R28C1	TRUE
R28C2	"OldFile"
R28C8	TRUE
R28C10	TRUE
R29C1	TRUE
R29C2	TRUE
R29C8	TRUE
R29C10	"Debug_Break"
R30C1	TRUE
R30C2	FALSE
R30C8	#N/A

R30C10	TRUE
R31C1	TRUE
R31C2	TRUE
R31C8	"31022.081643519"
R31C10	TRUE
R32C1	TRUE
R32C2	FALSE
R32C8	FALSE
R33C1	TRUE
R33C2	"NewFile"
R33C8	TRUE
R34C1	TRUE
R34C2	TRUE
R34C8	TRUE
R35C1	TRUE
R35C2	TRUE
R35C8	TRUE
R36C1	TRUE
R36C2	TRUE
R36C8	TRUE
R37C1	TRUE
R37C2	TRUE
R37C8	"AutoClose"
R38C1	TRUE
R38C2	TRUE
R38C8	TRUE
R39C1	TRUE
R39C2	TRUE
R39C8	TRUE
R40C1	TRUE
R40C2	TRUE
R40C8	TRUE
R41C1	TRUE
R41C2	TRUE
R41C8	"CloseDataFile"
R42C1	TRUE
R42C2	TRUE
R42C8	TRUE
R43C1	FALSE
R43C2	TRUE
R43C8	"31022.081643519"
R44C1	FALSE
R44C2	"31022.081643519"
R44C8	FALSE
R45C1	TRUE
R45C2	"Present"
R45C8	TRUE
R46C1	TRUE
R46C2	TRUE
R46C8	TRUE
R47C1	TRUE
R47C2	TRUE
R47C8	4
R48C1	TRUE
R48C2	TRUE
R48C8	FALSE
R49C1	TRUE
R49C2	TRUE
R49C8	TRUE
R50C1	TRUE
R50C2	TRUE
R50C8	FALSE
R51C1	TRUE
R51C2	TRUE
R51C8	TRUE
R52C1	TRUE
R52C2	TRUE
R52C8	TRUE
R53C1	TRUE
R53C8	TRUE

R54C1	"Append.data"
R54C8	TRUE
R55C1	TRUE
R55C2	"Appends data to the chosen"
R55C8	TRUE
R56C1	TRUE
R56C2	"database from an inter-"
R56C8	TRUE
R57C1	"Scrap"
R57C2	"mediate file and sets the"
R57C8	"SaveData"
R58C1	FALSE
R58C2	"new database range."
R58C8	FALSE
R59C1	TRUE
R59C8	FALSE
R60C1	TRUE
R60C8	FALSE
R61C1	FALSE
R61C8	FALSE
R62C1	"Scrap"
R62C8	"Restart"
R63C1	TRUE
R63C8	#N/A
R64C1	TRUE
R64C8	"'Phase.Enter"
R65C1	TRUE
R65C8	TRUE
R66C1	FALSE
R67C1	TRUE
R68C1	TRUE
R69C1	TRUE
R70C1	TRUE
R71C1	TRUE
R72C1	TRUE
R73C1	TRUE
R74C1	TRUE
R75C1	TRUE
R76C1	4
R77C1	TRUE
R78C1	#VALUE!
R79C1	TRUE

Cross reference of Excel file *PhaseEntry

Names with cell references

R9C5	Al2O3
R4C7	a_Ox.
R7C7	CaO
R5C7	CatTot
R7C5:R12C5,R7C7:R10C7	clz
R10C7	Cr2O3
R3C3	Description
R3C3:R4C3,R2C5:R4C5,R2C7:R5C7,R7C5:R12C5,R7C7:R10C7,R2C3	Entry
R7C5:R12C5,R7C7:R10C7	EntryOxides
R10C5	FeO
R1C10:R1C57	Fields
R9C7	K2O
R1C2	Marker
R12C5	MgO
R11C5	MnO
R2C7	n
R8C7	Na2O
R3C7	OH
R2C20:R2C29	Oxarray
R4C31:R7C33	OxideFactor
R3C20:R3C29	Oxides

R2C5	Phase
R4C5	Point
R2C10:R2C57	Record
R4C3	Remarks
R2C3	Sample_Id.
R7C5	SiO2
R3C5	Spot
R8C5	TiO2

Names with values.

R1C1	"Start.Up"

Cells with formulas.

R2C10	Sample_Id.
R2C11	Description
R2C12	Remarks
R2C13	Phase
R2C14	Spot
R2C15	Point
R2C16	n
R2C17	OH
R2C18	a_Ox.
R2C19	CatTot
R2C30	SUM(RC[-10]:RC[-1])
R2C31	IF(RC[-12]>0,RC[+19]*71.85/(R3C33*R3C32/R3C31),0)
R2C32	IF(RC[-13]>0,RC[+19]*79.95/(R3C33*R3C32/R3C31),0)
R2C33	IF(RC[-16]=0,0,RC[-16]*18.016*RC[+25]/(2*RC[-15]))
R2C34	RC[-4]+RC[-1]-IF(RC[-15]>0,RC[-11],)+RC[-2]+RC[-3]
R2C35	(RC[-15]*2/60.09)*(RC[-17]/RC[+23])*(1/2)
R2C36	(RC[-14]*3/101.94)*(RC[-18]/RC[+22])*(2/3)
R2C37	(RC[-16]*2/79.899)*(RC[-19]/RC[+21])*(1/2)
R2C38	(RC[-15]/71.846)*(RC[-20]/RC[+20])
R2C39	(RC[-15]/70.937)*(RC[-21]/RC[+19])
R2C40	(RC[-15]/40.304)*(RC[-22]/RC[+18])
R2C41	(RC[-15]/56.079)*(RC[-23]/RC[+17])
R2C42	(RC[-15]/61.979)*(RC[-24]/RC[+16])*2
R2C43	(RC[-15]/94.795)*(RC[-25]/RC[+15])*2
R2C44	(RC[-15]*3/152.02)*(RC[-26]/RC[+14])*(2/3)
R2C45	RC[-28]
R2C46	SUM(RC[-11]:RC[-1])
R2C47	IF(RC[-28]>0,RC[-12]*RC[-28]/RC[-1],0)
R2C48	IF(RC[-29]>0,RC[-12]*RC[-29]/RC[-2],0)
R2C50	IF(RC[-31]>0,RC[-12]*RC[-31]/RC[-4]-RC[+1],0)
R2C51	IF(RC[-32]>0,2*(RC[-33]-(RC[-4]*2+RC[-3]*3/2+RC[-2]*2+RC[+1]+RC[+2]+RC[+3]+RC[+4]*2+RC[+5]*2+RC[+6]*3/2+RC[-13]*RC[-32]/RC[-5])),0)
R2C52	IF(RC[-33]>0,RC[-13]*RC[-33]/RC[-6],0)
R2C53	IF(RC[-34]>0,RC[-13]*RC[-34]/RC[-7],0)
R2C54	IF(RC[-35]>0,RC[-13]*RC[-35]/RC[-8],0)
R2C55	IF(RC[-36]>0,RC[-13]*RC[-36]/RC[-9],0)
R2C56	IF(RC[-37]>0,RC[-13]*RC[-37]/RC[-10],0)
R2C57	IF(RC[-38]>0,RC[-13]*RC[-38]/RC[-11],0)
R2C58	(RC[-38]*2/60.09)+(RC[-36]*3/101.961)+(RC[-37]*2/79.899)+RC[-35]/71.846+(RC[-34]/70.937)+(RC[-33]/40.304)+(RC[-32]/56.079)+(RC[-31]/61.979)+(RC[-30]/94.195)+(RC[-29]*3/151.99)
R3C20	SiO2
R3C21	TiO2
R3C22	Al2O3
R3C23	FeO
R3C24	MnO
R3C25	MgO
R3C26	CaO
R3C27	Na2O
R3C28	K2O
R3C29	Cr2O3
R3C31	R4C31
R3C32	R4C32
R3C33	R4C33
R4C31	R2C25

R4C33	R2C53
R5C31	R2C22
R5C33	R2C48
R6C31	R2C21
R6C33	R2C49
R7C31	R2C29
R7C33	R2C57

Values of cells.

R1C10	"Sample Id."
R1C11	"Description"
R1C12	"Remarks"
R1C13	"Phase"
R1C14	"Spot"
R1C15	"Point"
R1C16	"n"
R1C17	"OH"
R1C18	"a Ox."
R1C19	" +7 +"
R1C20	"SiO2"
R1C21	"TiO2"
R1C22	"Al2O3"
R1C23	"FeO*"
R1C24	"MnO"
R1C25	"MgO"
R1C26	"CaO"
R1C27	"Na2O"
R1C28	"K2O"
R1C29	"Cr2O3"
R1C30	"Total"
R1C31	"FeO Nx"
R1C32	"Fe2O3 Nx"
R1C33	"H2O"
R1C34	"Total Nx"
R1C35	"Si"
R1C36	"Al"
R1C37	"Ti"
R1C38	"Fe"
R1C39	"Mn"
R1C40	"Mg"
R1C41	"Ca"
R1C42	"Na"
R1C43	"K"
R1C44	"Cr"
R1C45	"OH"
R1C46	"Total"
R1C47	"Si Nx"
R1C48	"Al Nx"
R1C49	"Ti Nx"
R1C50	"Fe 2+ Nx"
R1C51	"Fe 3+ Nx"
R1C52	"Mn Nx"
R1C53	"Mg Nx"
R1C54	"Ca Nx"
R1C55	"Na Nx"
R1C56	"K Nx"
R1C57	"Cr Nx"
R1C58	"Z factor"
R2C2	"Sample Id."
R2C4	"Phase"
R2C6	"n"
R2C7	1
R2C16	1
R2C18	1
R2C20:R2C29	{1.5,2.5,3.5,4.5,5.5,6.5,7.5,8.5,0,0}
R2C21	2.5
R2C22	3.5
R2C23	4.5
R2C24	5.5
R2C25	6.5

R2C26	7.5
R2C27	8.5
R2C30	40
R2C34	40
R2C35	0.031686024201229
R2C36	0.087162987115055
R2C37	0.039717084365926
R2C38	0.079503933173114
R2C39	0.098416647338579
R2C40	0.20471228269547
R2C41	0.16976169281298
R2C42	0.34816334890077
R2C46	1.0591240006031
R2C58	0.78780966672313
R3C2	"Description"
R3C4	"Spot"
R3C6	"OH"
R3C31	6.5
R3C32	40.32
R4C2	"Remarks"
R4C4	"Point"
R4C6	"a Ox."
R4C7	1
R4C31	6.5
R4C32	40.32
R5C6	" +7+"
R5C31	3.5
R5C32	50.97
R6C2	"Am="
R6C3	"Amphibole"
R6C31	2.5
R6C32	79.9
R7C2	"Cp="
R7C3	"Clinopyroxene"
R7C4	"SiO2"
R7C6	"CaO"
R7C32	76.01
R8C2	"Pl="
R8C3	"Plagioclase"
R8C4	"TiO2"
R8C6	"Na2O"
R9C2	"Mt="
R9C3	"Magnetite"
R9C4	"Al2O3"
R9C6	"K2O"
R10C2	"Ch="
R10C3	"Chromite"
R10C4	"FeO"
R10C6	"Cr2O3"
R11C2	"Mu="
R11C3	"Muscovite"
R11C4	"MnO"
R12C2	"Cl="
R12C3	"Chlorite"
R12C4	"MgO"

WHOLE ROCK ENTRY - AN AUTOMATED DATA ENTRY FORM/DATABASE GENERATOR FOR WHOLE ROCK MAJOR AND TRACE ELEMENT DATA.

Environment: Excel™, version 1.05 or greater
Installed resources: n.a.

This is basically the whole rock version of Phase Entry. It calculates FeO and Fe_2O_3 values based on the ratio: $Fe^{2+}/Fe^{3+} = 0.85$ and has an option to calculate a "tholeiitic norm"

(see Appendix 1). Unlike Phase Enter, a calculation sheet is also required all four worksheets must be open for the macro to run without error.

The sheets have not been updated to take advantage of Excel™ version 1.5's programmable menus, dialog boxes and auto-execute features but may well be in future.

Cross reference of Excel file *WREntry

Names with cell references

R4C5	Al2O3
R8C9	Ba
R9C5	CaO
R11C9	Ce
R3C9	Cr
R4C2	Description
R6C2	D_1
R8C2	D_2
R10C2	D_3
R2C2,R4C2,R6C2,R8C2,R10C2,R12C2,R14C2,R2C5:R13C5,R2C9:R14C9	Entry
R16C3	Error
R5C5	Fe2O3
R6C5	FeO
R11C5	K2O
R10C9	La
R13C5	LOI
R8C5	MgO
R7C5	MnO
R10C5	Na2O
R12C9	Nd
R15C3	Norm
R12C5	P2O5
R14C2	Pair
R9C9	Pb
R4C9	Rb
R2C2	Sample_Id.
R2C5	SiO2
R5C9	Sr
R12C2	Tag
R13C9	Th
R3C5	TiO2
R14C5	Total
R14C9	U
R2C9	V
R2C9:R14C9,R2C5:R13C5,R2C2	Values
R6C9	Y
R7C9	Zr

Names with values.

R1C10	"Sample Id."

Cells with formulas.

R14C5	SUM(R[-12]C:R[-1]C)

Values of cells.

R1C2	"Sample Id."
R1C4	",: ,: ,:Majors"
R1C8	" Traces"
R1C10	"Errors"
R2C4	"SiO2"
R2C8	"V"
R3C2	"Description"
R3C4	"TiO2"
R3C8	"Cr"
R4C4	"Al2O3"
R4C8	"Rb"

R5C2	"D_1"
R5C4	"Fe2O3*"
R5C8	"Sr"
R6C4	"FeO"
R6C8	"Y"
R7C2	"D_2"
R7C4	"MnO"
R7C8	"Zr"
R8C4	"MgO"
R8C8	"Ba"
R9C2	"D_3"
R9C4	"CaO"
R9C8	"Pb"
R10C4	"Na2O"
R10C8	"La"
R11C2	"Tag"
R11C4	"K2O"
R11C8	"Ce"
R12C4	"P2O5"
R12C8	"Nd"
R13C2	"Pair"
R13C4	"LOI"
R13C8	"Th"
R14C4	"Total"
R14C8	"U"
R15C2	"Calculate norm? "
R15C3	"Y"
R16C2	"Enter errors? "
R16C3	"N"

Cross reference of Excel file WREnter

Names with cell references

R2C25	aAl2O3
R2C36	ab
R2C30	aCaO
R2C27	aFe2O3
R2C26	aFeO
R2C32	aK2O
R2C29	aMgO
R2C28	aMnO
R2C37	an
R2C31	aNa2O
R2C48	ap
R2C33	aP2O5
R2C23	aSiO2
R2C24	aTiO2
R2C40	di_en
R2C41	di_fs
R2C39	di_wo
R2C45	fa
R2C44	fo
R2C42	hy_en
R2C43	hy_fs
R2C47	il
R2C46	mt
R2C38	ne
R2C35	or
R2C34	q
R2C1:R2C69	Record

Names with values.

R1C1	"WR.Entry"

Cells with formulas.

R2C1	'*WREntry'!Tag
R2C2	'*WREntry'!Pair

R2C3	'*WREntry'!Sample_Id.
R2C4	'*WREntry'!Description
R2C5	'*WREntry'!D_1
R2C6	'*WREntry'!D_2
R2C7	'*WREntry'!D_3
R2C8	'*WREntry'!SiO2
R2C9	'*WREntry'!TiO2
R2C10	'*WREntry'!Al2O3
R2C11	'*WREntry'!Fe2O3+'*WREntry'!FeO*1.111
R2C12	'*WREntry'!MnO
R2C13	'*WREntry'!MgO
R2C14	'*WREntry'!CaO
R2C15	'*WREntry'!Na2O
R2C16	'*WREntry'!K2O
R2C17	'*WREntry'!P2O5
R2C18	'*WREntry'!LOI
R2C19	'*WREntry'!Total
R2C20	RC[-9]*2*0.85*71.85/159.7
R2C21	RC[-10]*0.15
R2C22	RC[-3]-RC[-11]+RC[-2]+RC[-1]
R2C23	RC[-15]*100/(RC22-RC18)
R2C24	RC[-15]*100/(RC22-RC18)
R2C25	RC[-15]*100/(RC22-RC18)
R2C26	RC[-6]*100/(RC22-RC18)
R2C27	RC[-6]*100/(RC22-RC18)
R2C28	RC[-16]*100/(RC22-RC18)
R2C29	RC[-16]*100/(RC22-RC18)
R2C30	RC[-16]*100/(RC22-RC18)
R2C31	RC[-16]*100/(RC22-RC18)
R2C32	RC[-16]*100/(RC22-RC18)
R2C33	RC[-16]*100/(RC22-RC18)
R2C49	RC[-16]*4364.07
R2C50	RC[-26]*5994.99
R2C51	RC[-19]*8301.91
R2C52	'*WREntry'!V
R2C53	'*WREntry'!Cr
R2C54	'*WREntry'!Rb
R2C55	'*WREntry'!Sr
R2C56	'*WREntry'!Y
R2C57	'*WREntry'!Zr
R2C58	'*WREntry'!Ba
R2C59	'*WREntry'!Pb
R2C60	'*WREntry'!La
R2C61	'*WREntry'!Ce
R2C62	'*WREntry'!Nd
R2C63	'*WREntry'!Th
R2C64	'*WREntry'!U

Values of cells.

R1C1	"Tag"
R1C2	"Pair"
R1C3	"Sample Id."
R1C4	"Description"
R1C5	"D_1"
R1C6	"D_2"
R1C7	"D_3"
R1C8	"SiO2"
R1C9	"TiO2"
R1C10	"Al2O3"
R1C11	"Fe2O3"
R1C12	"MnO"
R1C13	"MgO"
R1C14	"CaO"
R1C15	"Na2O"
R1C16	"K2O"
R1C17	"P2O5"
R1C18	"LOI"
R1C19	"Total"
R1C20	"FeOc"
R1C21	"Fe2O3c"

R1C22	"Totalc"
R1C23	"aSiO2"
R1C24	"aTiO2"
R1C25	"aAl2O3"
R1C26	"aFeO"
R1C27	"aFe2O3"
R1C28	"aMnO"
R1C29	"aMgO"
R1C30	"aCaO"
R1C31	"aNa2O"
R1C32	"aK2O"
R1C33	"aP2O5"
R1C34	"q"
R1C35	"or"
R1C36	"ab"
R1C37	"an"
R1C38	"ne"
R1C39	"di wo"
R1C40	"di en"
R1C41	"di fs"
R1C42	"hy en"
R1C43	"hy fs"
R1C44	"fo"
R1C45	"fa"
R1C46	"mt"
R1C47	"il"
R1C48	"ap"
R1C49	"P"
R1C50	"Ti"
R1C51	"K"
R1C52	"V"
R1C53	"Cr"
R1C54	"Rb"
R1C55	"Sr"
R1C56	"Y"
R1C57	"Zr"
R1C58	"Ba"
R1C59	"Pb"
R1C60	"La"
R1C61	"Ce"
R1C62	"Nd"
R1C63	"Th"
R1C64	"U"
R1C65	"Cr err."
R1C66	"Ba err."
R1C67	"Zr err."
R1C68	"Y err."
R1C69	"Sr err."
R2C23	#DIV/0!
R2C24	#DIV/0!
R2C25	#DIV/0!
R2C26	#DIV/0!
R2C27	#DIV/0!
R2C28	#DIV/0!
R2C29	#DIV/0!
R2C30	#DIV/0!
R2C31	#DIV/0!
R2C32	#DIV/0!
R2C33	#DIV/0!
R2C35	1.9750901575907
R2C36	33.517957154257
R2C37	33.550347670488
R2C39	4.0732516423815
R2C40	2.1881993098971
R2C41	1.7466563660597
R2C42	7.9842963336211
R2C43	6.3731955112821
R2C44	2.4385607752186
R2C45	2.148732628812
R2C46	2.0840752803565

R2C47	1.9483513579332
R2C48	0.37646474730046
R2C49	#DIV/0!
R2C50	#DIV/0!
R2C51	#DIV/0!

Cross reference of Excel file WRInter

Names with cell references

R2C1:R2C69	Record

Names with values.

R1C1	"Tag"

Cells with formulas.

R2C1:R2C69	Record

Values of cells.

R1C1	"Tag"
R1C2	"Pair"
R1C3	"Sample Id."
R1C4	"Description"
R1C5	"D_1"
R1C6	"D_2"
R1C7	"D_3"
R1C8	"SiO2"
R1C9	"TiO2"
R1C10	"Al2O3"
R1C11	"Fe2O3"
R1C12	"MnO"
R1C13	"MgO"
R1C14	"CaO"
R1C15	"Na2O"
R1C16	"K2O"
R1C17	"P2O5"
R1C18	"LOI"
R1C19	"Total"
R1C20	"FeOc"
R1C21	"Fe2O3c"
R1C22	"Totalc"
R1C23	"aSiO2"
R1C24	"aTiO2"
R1C25	"aAl2O3"
R1C26	"aFeO"
R1C27	"aFe2O3"
R1C28	"aMnO"
R1C29	"aMgO"
R1C30	"aCaO"
R1C31	"aNa2O"
R1C32	"aK2O"
R1C33	"aP2O5"
R1C34	"q"
R1C35	"or"
R1C36	"ab"
R1C37	"an"
R1C38	"ne"
R1C39	"di wo"
R1C40	"di en"
R1C41	"di fs"
R1C42	"hy en"
R1C43	"hy fs"
R1C44	"fo"
R1C45	"fa"
R1C46	"mt"
R1C47	"il"
R1C48	"ap"
R1C49	"P"

R1C50	"Ti"
R1C51	"K"
R1C52	"V"
R1C53	"Cr"
R1C54	"Rb"
R1C55	"Sr"
R1C56	"Y"
R1C57	"Zr"
R1C58	"Ba"
R1C59	"Pb"
R1C60	"La"
R1C61	"Ce"
R1C62	"Nd"
R1C63	"Th"
R1C64	"U"
R1C65	"Cr err."
R1C66	"Ba err."
R1C67	"Zr err."
R1C68	"Y err."
R1C69	"Sr err."

Cross reference of Excel file WR.Entry
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Names with cell references

R118C1	Append.data
R98C1	NoNorm
R6C1	NORM
R113C1	PasteIt
R122C2:R16384C2	Recorder
R1C1	WR.Entry

Names with values.

54.781435756637	ab
0.055965090881432	Al
15.558295265038	an
0.20152709777759	ap
-0.038018156853901	Ca
-0.038018156853901	di
-1.3376754443166	di_en
0	di_fs
-4.4101061950525	di_wo
0	fa
0.037007170271978	Feii
0.0043046333238916	Feiii
0	fo
0.095114923534119	hy
3.3466350851405	hy_en
8.1376115941182	hy_fs
1.2678702442199	il
0.013496943396805	K
0.095114923534119	M
0.020089596408239	Mg
0.99867493114284	mt
0.10454472472641	Na
0	ne
0	ol
7.5043005286236	or
0.00065008741218576	P
17.363911216307	q
0.28896507266279	Si
0.0083412516067097	Ti
0.35185173480584	XM
-0.28896507266279	XS

Cells with formulas.

R2C1	ECHO(FALSE)
R3C1	CALCULATE.NOW()

```
R4C1    MESSAGE(TRUE,"Entering record ,9")
R5C1    IF('*WREntry'!Norm="Y",GOTO(R[+1]C),GOTO(R[+93]C))
R7C1    MESSAGE(TRUE,"Calculating norm ,9")
R8C1    SET.NAME("Si",WREnter!aSiO2/60.09)
R9C1    SET.NAME("Ti",WREnter!aTiO2/79.9)
R10C1   SET.NAME("Al",WREnter!aAl2O3/101.94)
R11C1   SET.NAME("Feiii",WREnter!aFe2O3/159.7)
R12C1   SET.NAME("Feii",WREnter!aFeO/71.85+WREnter!aMnO/70.94)
R13C1   SET.NAME("Mg",WREnter!aMgO/40.32)
R14C1   SET.NAME("Ca",WREnter!aCaO/56.08)
R15C1   SET.NAME("Na",WREnter!aNa2O/61.984)
R16C1   SET.NAME("K",WREnter!aK2O/94.2)
R17C1   SET.NAME("P",WREnter!aP2O5/141.95)
R52C1   MESSAGE(TRUE,"Entering norm values ,9")
R53C1   FORMULA.GOTO(WREnter!q)
R54C1   FORMULA.ARRAY(GET.NAME("q"))
R55C1   PasteIt()
R56C1   FORMULA.GOTO(WREnter!or)
R57C1   FORMULA.ARRAY(GET.NAME("or"))
R58C1   PasteIt()
R59C1   FORMULA.GOTO(WREnter!ab)
R60C1   FORMULA.ARRAY(GET.NAME("ab"))
R61C1   PasteIt()
R62C1   FORMULA.GOTO(WREnter!an)
R63C1   FORMULA.ARRAY(GET.NAME("an"))
R64C1   PasteIt()
R65C1   FORMULA.GOTO(WREnter!ne)
R66C1   FORMULA.ARRAY(GET.NAME("ne"))
R67C1   PasteIt()
R68C1   FORMULA.GOTO(WREnter!di_wo)
R69C1   FORMULA.ARRAY(GET.NAME("di_wo"))
R70C1   PasteIt()
R71C1   FORMULA.GOTO(WREnter!di_en)
R72C1   FORMULA.ARRAY(GET.NAME("di_en"))
R73C1   PasteIt()
R74C1   FORMULA.GOTO(WREnter!di_fs)
R75C1   FORMULA.ARRAY(GET.NAME("di_fs"))
R76C1   PasteIt()
R77C1   FORMULA.GOTO(WREnter!hy_en)
R78C1   FORMULA.ARRAY(GET.NAME("hy_en"))
R79C1   PasteIt()
R80C1   FORMULA.GOTO(WREnter!hy_fs)
R81C1   FORMULA.ARRAY(GET.NAME("hy_fs"))
R82C1   PasteIt()
R83C1   FORMULA.GOTO(WREnter!fo)
R84C1   FORMULA.ARRAY(GET.NAME("fo"))
R85C1   PasteIt()
R86C1   FORMULA.GOTO(WREnter!fa)
R87C1   FORMULA.ARRAY(GET.NAME("fa"))
R88C1   PasteIt()
R89C1   FORMULA.GOTO(WREnter!mt)
R90C1   FORMULA.ARRAY(GET.NAME("mt"))
R91C1   PasteIt()
R92C1   FORMULA.GOTO(WREnter!il)
R93C1   FORMULA.ARRAY(GET.NAME("il"))
R94C1   PasteIt()
R95C1   FORMULA.GOTO(WREnter!ap)
R96C1   FORMULA.ARRAY(GET.NAME("ap"))
R97C1   PasteIt()
R99C1   MESSAGE(TRUE,"Entering record into WRInter ,9")
R100C1  FORMULA.GOTO(WREnter!Record)
R101C1  COPY()
R102C1  FORMULA.GOTO(WRInter!Record)
R103C1  PASTE.SPECIAL(4)
R104C1  PASTE.SPECIAL(3)
R105C1  SELECT(OFFSET(SELECTION(),1,0))
R106C1  DEFINE.NAME("Record")
R107C1  ACTIVATE("*WREntry")
R108C1  SELECT('*WREntry'!Values)
R109C1  CLEAR()
```

R110C1	SELECT("'WREntry'!Entry,"'WREntry'!Sample_Id.)
R111C1	MESSAGE(TRUE,"Enter record ,9 (Shift-Option-Cmnd.-E)")
R112C1	RETURN()
R114C1	COPY()
R115C1	PASTE.SPECIAL(3)
R116C1	RETURN()
R119C1	MESSAGE(TRUE,"Appending data ,9")
R120C1	FORMULA.GOTO(WRInterlRecord)
R121C1	SELECT(OFFSET(WRInterlRecord,-1,0):WRInterlR2C1)
R122C1	COPY()
R123C1	OPEN("DD 20:Excel:Databases:WR Anal. dB")
R124C1	FORMULA.GOTO(lDatabase)
R125C1	SELECT(OFFSET(ACTIVE.CELL(),ROWS(SELECTION()),0))
R126C1	PASTE.SPECIAL(3)
R127C1	FORMULA.GOTO(SELECTION():lDatabase)
R128C1	SET.DATABASE()
R129C1	SAVE()
R130C1	MESSAGE(FALSE)
R131C1	RETURN()

Values of cells.

R1C1	"WR.Entry"
R2C1	TRUE
R2C2	"Accepts WR chemistry data from WREntry"
R3C1	TRUE
R3C2	"form and generates anhydrous and Fe2O3"
R4C1	TRUE
R4C2	"and FeO values (using Fe2+/Fe3+=0.85),"
R5C1	TRUE
R5C2	"a tholeiitic norm (no leucite or corundum)"
R6C1	"NORM"
R6C2	"if desired, and ppm values for K,Ti and P."
R7C1	TRUE
R7C2	"Norm calculations will be made if the box"
R8C1	TRUE
R8C2	"on WREntry contains "Yes"."
R9C1	TRUE
R10C1	TRUE
R11C1	TRUE
R12C1	TRUE
R13C1	TRUE
R14C1	TRUE
R15C1	TRUE
R16C1	TRUE
R17C1	TRUE
R18C1	TRUE
R19C1	TRUE
R20C1	TRUE
R21C1	TRUE
R22C1	TRUE
R23C1	TRUE
R24C1	TRUE
R25C1	TRUE
R26C1	TRUE
R27C1	TRUE
R28C1	TRUE
R29C1	TRUE
R30C1	TRUE
R31C1	TRUE
R32C1	TRUE
R33C1	TRUE
R34C1	TRUE
R35C1	TRUE
R36C1	TRUE
R37C1	TRUE
R38C1	TRUE
R39C1	TRUE
R40C1	TRUE
R41C1	TRUE
R42C1	TRUE

R43C1	TRUE
R44C1	TRUE
R45C1	TRUE
R46C1	TRUE
R47C1	TRUE
R48C1	TRUE
R49C1	TRUE
R50C1	TRUE
R51C1	TRUE
R52C1	TRUE
R53C1	TRUE
R54C1	TRUE
R55C1	#N/A
R56C1	TRUE
R57C1	TRUE
R58C1	#N/A
R59C1	TRUE
R60C1	TRUE
R61C1	#N/A
R62C1	TRUE
R63C1	TRUE
R64C1	#N/A
R65C1	TRUE
R66C1	TRUE
R67C1	#N/A
R68C1	TRUE
R69C1	TRUE
R70C1	#N/A
R71C1	TRUE
R72C1	TRUE
R73C1	#N/A
R74C1	TRUE
R75C1	TRUE
R76C1	#N/A
R77C1	TRUE
R78C1	TRUE
R79C1	#N/A
R80C1	TRUE
R81C1	TRUE
R82C1	#N/A
R83C1	TRUE
R84C1	TRUE
R85C1	#N/A
R86C1	TRUE
R87C1	TRUE
R88C1	#N/A
R89C1	TRUE
R90C1	TRUE
R91C1	#N/A
R92C1	TRUE
R93C1	TRUE
R94C1	#N/A
R95C1	TRUE
R96C1	TRUE
R97C1	#N/A
R98C1	"NoNorm"
R99C1	TRUE
R100C1	TRUE
R101C1	TRUE
R102C1	TRUE
R103C1	TRUE
R104C1	TRUE
R105C1	TRUE
R106C1	TRUE
R107C1	TRUE
R108C1	TRUE
R109C1	TRUE
R110C1	TRUE
R111C1	TRUE
R112C1	TRUE

```
R113C1          "PasteIt"
R113C2          "Pastes the values in the intermediate"
R114C1          TRUE
R114C2          "sheet WRInter."
R115C1          TRUE
R116C1          TRUE
R117C1          "*****************************************"
R118C1          "Append.data"
R119C1          FALSE
R119C2          "Appends data to the database from WRInter "
R120C1          TRUE
R120C2          "file, and sets the new database range."
R121C1          TRUE
R122C1          TRUE
R123C1          TRUE
R124C1          TRUE
R125C1          TRUE
R126C1          TRUE
R127C1          TRUE
R128C1          TRUE
R129C1          TRUE
R130C1          FALSE
R131C1          TRUE
```

REFCHECK - A PROGRAMME FOR LISTING TAGGED TEXT IN A DOCUMENT FILE.

Source Environment: ZBasic, version 4.01 or greater
Installed resources: 1 BNDL, 1 RfCk, 1 FREF, 1 ICN#, 2 vers

RefCheck was originally written in Microsoft BASIC (interpreted) to list to the screen, a file and printer, text in a document file which had been "tagged" with uncommon characters. The purpose of this was so that bibliographic or other references could checked easily for their inclusion in the document. It was later compiled to an application with ZBasic with interface enhancements and the addition of a bibliographic reference "decoder" so that individual references were listed in a tab delimited, carriage return terminated format and could be used as criteria for searching an Excel™ or 4th Dimension™ reference database. In future it will become an integral part of a fast reference database, compiling and formatting program presently being written.

```
REM ** REFCHECK II**
REM ** © 1988 HR Ballard

DIM 255 SEARCH$, REFERENCE$, REF$(10), REF1$
TRON B
WINDOW OFF
COORDINATE WINDOW
DEF MOUSE=-1
APPLE MENU "^1 About RefCheck II..."
WINDOW 1,"", (20,30)-(493,200), 2
"Here"
CLS:Decode=2
TEXT 3,12,0,0
EDIT FIELD 1, "§",(210,110)-(250,125),1,2
BUTTON 1,1,"Go get 'em!",(180,150)-(280,170),1
BUTTON 2,1,"Tell me more!?",(350,150)-(470,170),1
BUTTON 3,1,"Quit now!!",(5,150)-(105,170),1
BUTTON 4,Decode,"", (220,50)-(240,63),2
"Repaint"
TEXT 3,18,1,0
```

```
PRINT@ (7,0) "§§§ REFCHECK §§§"
TEXT 3,12,0,0
PRINT@ (3,4) "Generates a listing of all text in a file which has been tagged"
PRINT@ (4,5) "with marker characters. Enter the character(s) used below."
TEXT 0,12,0,0:PRINT@ (12,2) "Decode references":TEXT 3,12,0,0
DIALOG ON

"Idle"
    IF DIALOG(0)<>1 THEN GOTO "Idle"
    IF DIALOG(1)=4 THEN Decode=-Decode+3:BUTTON 4,Decode:GOTO "Idle"

BELLYBUT=DIALOG(1)
IF BELLYBUT=2 THEN "Tellme"
IF BELLYBUT=3 THEN SYSTEM
MARKER$=EDIT$(1)
CLS:TEXT 3,18,1,0
PRINT:PRINT "              Select a file to check:"
TEXT 3,12,0,0
INFIL$=FILES$(1,"",,V%)
CLS
IF LEN(INFIL$)=0 THEN GOTO "Repaint"
CALL KILLCONTROLS(WINDOW(14))
OPEN "I",1,INFIL$,,V%
OUT$=INFIL$+MARKER$+".REFCK"
IF LEN(OUT$)=0 THEN END
OPEN "O",2,OUT$,,V%
CLS
PRINT@ (2,0) "Output file will be saved at the same directory level as: "
TEXT 3,12,1,0
PRINT@ (2,1) OUT$
TEXT 3,12,0,0
BEEP
PRINT@ (2,3) "Send output to printer?"
BUTTON 1,1, "Yes", (190,49)-(250,69),3 : BUTTON 2,1, "No", (290,49)-(350,69),3
PRINT@ (9,5) "Searching for text between:"
WHILE DIALOG(0)<>1
WEND
BUTTON CLOSE 1:BUTTON CLOSE 2
DIALOG OFF
ANSWER=DIALOG(1)
LONG IF ANSWER=1
BEEP
PRINT@ (2,3) "Select an output port:          "
BUTTON 1,1,"Modem",(190,49)-(255,69),3:BUTTON 2,1,"Printer",(290,49)-(355,69),3
DIALOG ON
WHILE DIALOG(0)<>1
WEND
DIALOG OFF
Port=-DIALOG(1)
BUTTON CLOSE 1:BUTTON CLOSE 2
END IF
IF ANSWER=1 THEN OPEN "C",Port,9600:HANDSHAKE PORT,-1:GOSUB "PRINTSET"
TEXT 4,9,0,0
Title$="References found with "+MARKER$+"..."
WINDOW 3,Title$,(3,40)-(512,340), 1
DO
    LINE INPUT #1, SEARCH$
    GOSUB "FindIt"
UNTIL EOF(1)

GOTO "quit"

"FindIt"
Find=INSTR(1,SEARCH$,MARKER$)
IF Find=0 THEN RETURN
LONG IF Flag%=1
    Flag%=0
    REFERENCE$=LeftOver$+MID$(SEARCH$,1,Find-1)
    FindEnd=Find+1
    GOTO "FoundIt"
```

```
END IF
FindEnd=INSTR(Find+1,SEARCH$,MARKER$)
IF FindEnd=0 THEN LeftOver$=MID$(SEARCH$,Find+1):Flag%=1:RETURN
REFERENCE$=MID$(SEARCH$,Find+1,FindEnd-Find-1)

"FoundIt"
SEARCH$=MID$(SEARCH$,FindEnd+1)
IF Decode<>1 THEN GOSUB "Decode" ELSE PREF$=REFERENCE$:GOSUB "PrintIt"
GOTO "FindIt"

"Decode"
REM***Remove parentheses***
        FindOP=INSTR(1,REFERENCE$,"(")
        IF FindOP<>0 THEN REFERENCE$=LEFT$(REFERENCE$,FindOP-
1)+MID$(REFERENCE$,FindOP+1)
        FindCP=INSTR(1,REFERENCE$,")")
        IF FindCP<>0 THEN REFERENCE$=LEFT$(REFERENCE$,FindCP-1)
        GOSUB "Remove"
RETURN

"Remove"
FindCol=1
    FOR X=1 TO 10
        FindCol=INSTR(FindCol,REFERENCE$,";")
        LONG IF FindCol=0
            REF$(X)=REFERENCE$
            GOSUB "RemoveII"
            RETURN
        XELSE
            REF$(X)=LEFT$(REFERENCE$,FindCol-1)
            GOSUB "RemoveII"
            REFERENCE$=MID$(REFERENCE$,FindCol+2)
        END IF
    NEXT
RETURN

"RemoveII"
    FindCom=INSTR(1,REF$(X),",")
    LONG IF FindCom=0
        Len%=LEN(REF$(X))
        PREF$=LEFT$(REF$(X),Len%-5)+CHR$(9)+RIGHT$(REF$(X),4):GOSUB "PrintIt"
        RETURN
    END IF
    REF1$=REF$(X)
    FindName=INSTR(1,REF$(X),",")
    Name$=LEFT$(REF$(X),FindName-6)
    DO
        PREF$=Name$+CHR$(9)+MID$(REF1$,FindCom-4,4):GOSUB "PrintIt"
        FindCom=INSTR(FindCom+1,REF1$,",")
    UNTIL FindCom=0
    PREF$=Name$+CHR$(9)+RIGHT$(REF1$,4):GOSUB "PrintIt"
RETURN

"PrintIt"
    PRINT PREF$:PRINT #2, PREF$
    FindTab=INSTR(1,PREF$,CHR$(9))
DO
    MID$(PREF$,FindTab,1)=" "
    IF ANSWER=1 THEN PRINT #Port, PREF$;CHR$(10)
    FindTab=INSTR(1,PREF$,CHR$(9))
UNTIL FindTab=0
RETURN

"PRINTSET"
WIDTH LPRINT -2
PRINT #Port, CHR$(27);CHR$(128);CHR$(48)
PRINT #Port, CHR$(27);CHR$(76);"010"
PRINT #Port, CHR$(27);CHR$(97);CHR$(48)
PRINT #Port, CHR$(27);CHR$(110)
PRINT #Port, CHR$(27);CHR$(33)
```

```
PRINT #Port, "References found in file:" ;CHR$(10)
PRINT #Port, INFIL$;CHR$(13);CHR$(10)
PRINT #Port, "Marker ";MARKER$;CHR$(13);CHR$(10)
PRINT #Port, CHR$(27);CHR$(34)
PRINT #Port, CHR$(27) CHR$(69)
RETURN
"quit"
IF ANSWER=1 THEN PRINT #Port, CHR$(12):CLOSE #Port
CLOSE #1
CLOSE #2
BEEP
TEXT 3,9,1,0:PRINT  "Jeez, that was quick!!"
BUTTON 1,1,"Go again?",(350,200)-(470,220),1
BUTTON 2,2,"Quit to Finder",(350,250)-(470,270),1
DIALOG ON
WHILE DIALOG(0)<>1
WEND
BUTTON CLOSE 1:BUTTON CLOSE 2
WINDOW CLOSE 3
IF DIALOG(1)=1 THEN "Here"
SYSTEM
"Tellme"
WINDOW 3, "Tell me more!",(10,30)-(500,320), 4
BUTTON 5,2,"Continue", (400,250)-(470,270),1
"RePaint"
TEXT 3,12,0,0:CLS
PRINT:PRINT "    The program will search ANY file for the text between two marker tags,"
PRINT "  e.g. would find "formatted word" in this bit of text using $ as the tag, and"
PRINT "  then list this to the screen, a file and printer. Screen output is only useful"
PRINT "  for previewing as it is lost off the top if there are numerous tags. It is"
PRINT "  possible to read $formatted word$ processor files and even MacDraw type"
PRINT "  files, but do this on a COPY!! The file is opened in this program and a crash"
PRINT "  could scramble the file."
PRINT "    Anything can be a marker string but the most useful ones are thing like"
PRINT "  $, #, @, Ÿ, / which aren't commonly used in documents."
PRINT
PRINT "    The reference decoding option can recognise these formats ONLY:"
PRINT "  $Fred (1988 )$  $Fred  1988, 1989$  $Fred 1988; Ethel 1989$"
PRINT "  Colon separated multiple references are limited to 10, comma separated"
PRINT "  multiple references are unlimited. N.B. COMMAS ONLY AFTER YEAR!!"
TEXT 3,9,0,0:PRINT "                                    PRESS MOUSE BUTTON FOR WORD 3 NOTES"
PRINT@ (18,22) " Written by H.R. Ballard, 1988."
MOUSE ON:DIALOG ON
WHILE MOUSE(0)=0
 IF DIALOG(0)=1 THEN "CloseWindow"
WEND
IF MOUSE(0)=-1 THEN GOSUB "PopUp"
GOTO "RePaint"

"CloseWindow"
FLUSHEVENTS
MOUSE OFF:WINDOW CLOSE 3
GOTO "Repaint"
END

"PopUp"
WINDOW 4,"",(100,100)-(350,150),16
WINDOW OUTPUT 4
PRINT "To use RefCheck II with Word 3, save a copy of the file to be checked in Text Only format or without
the Fast Save option."
    WHILE MOUSE(0)=-1
    WEND
WINDOW CLOSE 4
RETURN
```

DIGITDRAWII - A PROGRAMME FOR PRODUCING PICT FILES OF NUMERICALLY DEFINED OBJECTS.

Source Environment: ZBasic, version 4.01 or greater
Installed resources: 1 BNDL, 1 DLOG, 1 DITL, 1 DDrw,1 PICT, 1 vers

DigitDrawII generates Macintosh geometric objects from text data files. Objects available are polygons (a single object which may be open or closed consisting of a sequence of up to 32 767 connected lines), lines and points. Data is read from a text file of records which are tab delimited, carriage return terminated in the order of X (increasing to the right) and Y (increasing down). The X and Y values are pixel co-ordinates with the origin at the upper left corner of the screen. Co-ordinate values must be limited to ±32 767 and are rounded to the nearest integer. Object data sets are preceded by any identifying string which must begin with P or L for polygons and lines respectively and p for points. For polygons lines are drawn beginning at the starting point and connecting successive points. Two successive identical records will produce a cusp (see the MacDraw manual for the implications of this). Lines are drawn using a pair of records defining the end points. If there is an odd number of records in the lines data set the last record is ignored. Points are single records. A sample data file is presented below the listing and generates a portion of the topographic profile of the cross section included in the pocket.

Objects generated are saved in a PICT file type format and given a MacDrawII creator signature so they may be double-clicked to launch MacDrawII, although the files may be opened by any application which can read PICT type files.

The program in future will include a help screen and read files produced by a newer version of Digitizer (see above) so that data files may be in units other than pixels, use either the standard Macintosh or Cartesian co-ordinate plane orientations with a translated origin, work on large screens and include colour information with Colour Quickdraw.

```
'**** DigitDrawII***
'****© by H.R. Ballard, 6/89 ***

'****Define environment
DEFMOUSE=1:WINDOW OFF:TEXT 0,12
COORDINATE WINDOW:WIDTH -2
WINDOW 1,,(0,20)-(512,342),3
APPLE MENU "About DigitDraw..."
MENU 1,0,1,"File"
MENU 1,1,1,"Open data file..."
MENU 1,3,1,"Quit"

'****Array base 0***
DIM ClipRect(4),ScalePic(4),63 Alert$(4)
Alert$(0)="The object data set header...":Alert$(2)="is not defined. Save drawing now?"
Alert$(3)="(No will continue the drawing.)"

'****Trap menu events
"MenuTrap"
```

```
ON MENU GOSUB "MenuHandle"
MENU ON
DO
UNTIL menu

"MenuHandle"
MENU OFF
MenuNum=MENU(0):MenuItem=MENU(1)
IF MenuNum=1 AND MenuItem=3 THEN "End"
IF MenuNum=255 THEN GOSUB "AboutDigitDraw"
IF MenuNum=1 AND MenuItem=1 THEN GOSUB "Begin"
RETURN

"AboutDigitDraw"
MENU
dID=1:Dsto&=0:BWptr&=-1
DPtr&=FN GETNEWDIALOG(dID,Dsto&,BWptr&)
"Dialog0Idle"
CALL MODALDIALOG(0,item%)
IF item%<>1 THEN GOTO "Dialog0Idle"
CALL DISPOSDIALOG(DPtr&)
DIALOG OFF:IHndl&=MEM(-1)
RETURN

"Begin"
File$=FILES$(1,"TEXT",,vol%)
MENU
CURSOR 4
IF File$="" THEN "End"
CLS
OPEN "I",1,File$,,vol%
GOSUB "MaxMin"
RECORD 1,0
LINE INPUT #1, Object$
DO
    SELECT LEFT$(Object$,1)
        CASE "P"
            Object=1
        CASE "L"
            Object=2
        CASE "p"
            Object=3
        CASE ELSE
            Object=4
    END SELECT
    ON Object GOSUB "Polygon", "Line", "Point","Nada", "End"
UNTIL EOF(1)
GOSUB "SaveObject"
CLS
RETURN

"MaxMin"
PRINT@ (10,10) "Calculating drawing region..."
MMFlag=0
WHILE NOT EOF(1)
"NextRec"
    LINE INPUT #1, Dummy$
    X!=VAL(Dummy$)
    IF Dummy$="P" OR  Dummy$="L" THEN GOTO "NextRec"
    Y!=VAL(MID$(Dummy$,INSTR(0,Dummy$,CHR$(9))+1))
    IF MMFlag=0 THEN MMFlag=1:MaxX!=X!:MinX!=X!:MaxY!=Y!:MinY!=Y!:GOTO "NextRec"
    IF X!>MaxX! THEN MaxX!=X!
    IF Y!>MaxY! THEN MaxY!=Y!
    IF X!<MinX! THEN MinX!=X!
    IF Y!<MinY! THEN MinY!=Y!
WEND
"NewObject"
CLS
CALL SETRECT (ClipRect(0),MinX!,MinY!,MaxX!,MaxY!)
CALL CLIPRECT (ClipRect(0))
```

```
Width!=MaxX!-MinX!:Height!=MaxY!-MinY!:Aspect!=Width!/Height!

"***Determine size and offset of scaled rectangle.***
SELECT Aspect!
    CASE >1
        ScalePic(0)=20
        ScalePic(1)=0+2
        ScalePic(2)=322/Aspect!+20
        ScalePic(3)=512-2
    CASE <=1
        ScalePic(0)=10
        ScalePic(1)=0
        ScalePic(2)=342
        ScalePic(3)=502*Aspect!
END SELECT

H&=FN OPENPICTURE (ClipRect(0))
CALL SHOWPEN
RETURN

"Polygon"
LINE INPUT #1, Dummy$
X!=VAL(Dummy$)
Y!=VAL(MID$(Dummy$,INSTR(0,Dummy$,CHR$(9))+1))
CALL MOVETO (X!,Y!)
Poly&=FN OPENPOLY
CALL HIDEPEN
WHILE NOT EOF(1)
    LINE INPUT #1, Dummy$
    PlotX!=VAL(Dummy$)
    LONG IF PlotX!=0
        LONG IF ASC(Dummy$)<48 OR ASC(Dummy$)>57
            Object$=Dummy$
            GOTO "ClosePoly"
        END IF
    END IF
    PlotY!=VAL(MID$(Dummy$,INSTR(0,Dummy$,CHR$(9))+1))
    CALL LINETO (PlotX!,PlotY!)
WEND
"ClosePoly"
CALL CLOSEPOLY
CALL SHOWPEN
CALL FRAMEPOLY (Poly&)
CALL KILLPOLY (Poly&)*
RETURN

"Line"
WHILE NOT EOF(1)
    LINE INPUT #1, Dummy$
    IF ASC(Dummy$)<48 OR ASC(Dummy$)>57 THEN Object$=Dummy$:RETURN
    X!=VAL(Dummy$)
    Y!=VAL(MID$(Dummy$,INSTR(0,Dummy$,CHR$(9))+1))
    CALL MOVETO (X!,Y!)
    IF NOT EOF(1) LINE INPUT #1, Dummy$ ELSE RETURN
    X1!=VAL(Dummy$)
    IF ASC(Dummy$)<48 OR ASC(Dummy$)>57 THEN Object$=Dummy$:RETURN
    Y1!=VAL(MID$(Dummy$,INSTR(0,Dummy$,CHR$(9))+1))
    CALL LINETO (X1!,Y1!)
WEND
RETURN

"Point"
        WHILE NOT EOF(1)
            LINE INPUT #1, Dummy$
            IF ASC(Dummy$)<48 OR ASC(Dummy$)>57 THEN Object$=Dummy$:RETURN
            X!=VAL(Dummy$)
            Y!=VAL(MID$(Dummy$,INSTR(0,Dummy$,CHR$(9))+1))
            PLOT X!,Y!
        WEND
RETURN
```

```
"Nada"
Alert$(1)=Object$
CALL PARAMTEXT (Alert$(0),Alert$(1),Alert$(2),Alert$(3))
CURSOR 0
Alert=FN STOPALERT (3,0)
LONG IF Alert=1:'Abort drawing
    GOSUB "SaveObject"
    FLUSHEVENTS
    CLS
    GOTO "MenuTrap"
XELSE
    CURSOR 4
    WHILE NOT EOF(1)
        LINE INPUT #1, Dummy$
        IF ASC(Dummy$)<48 OR ASC(Dummy$)>57 THEN Object$=Dummy$:RETURN
    WEND
END IF

"SaveObject"
CALL CLOSEPICTURE
CLOSE 1:CLS
CALL SETRECT (ClipRect(0),0,0,512,342)
CALL CLIPRECT (ClipRect(0))
PICTURE (ScalePic(1),ScalePic(0))-(ScalePic(3),ScalePic(2)),H&
CURSOR 0
PRINT@ (10,0) "Scaled image. Click mouse to continue..."
DO
UNTIL FN BUTTON
FLUSHEVENTS
DEF OPEN "PICTMDPL":' Define file as MacDrawII,PICT type
File$=File$+".PICT"
F$=FILES$(0,"Save PICT Image as:",File$,V%)
IF F$="" THEN RETURN
CURSOR 4
OPEN "O",2,F$,1,V%:      ' CREATE A NEW FILE
FOR I=0 TO 255:      ' WRITE FILE HEADER OF 512 BYTES
  WRITE #2, Zero%:  ' 256 WORDS OF 0000 = 512 BYTES (HEADER)
NEXT
Z=FN HLOCK(H&):P&=PEEK LONG(H&)
PictL&=FN GETHANDLESIZE(H&)
WRITE FILE #2,P&,PictL&
Z=FN HUNLOCK(H&):KILL PICTURE H&
CURSOR 0
RETURN
```

Sample data for a polygon representing a portion of a topographic profile.

```
P
-25.512     272.352
-17.008     270.624
-5.669      272.352
0           272.352
28.346      265.44
85.039      258.528
107.717     251.616
116.22      244.704
124.724     237.792
144.567     230.88
153.071     223.968
161.575     217.056
175.748     210.144
188.504     203.232
218.268     203.232
232.441     210.144
253.701     217.056
```

STEP-SCAN

Source Environment: JCASS/DEC PDP 8/f with interface to JEOL JX-5A microprobe
Installed resources: n.a.

Step Scan automatically drives the x and y positioning motors, collects counts on three peaked spectrometers and displays the results in tabular or graphical form. Although the PDP 8/f and interface have been replaced, the program should be easily ported to the new environment. The program listing begins on the page following.

```
*W
C JECASS-X- 5A                                    of step-scan prog.
01.01 C VERSION 1.1
01.05 C INIT.,TABLE HEADING,COUNT LOOP
01.10 T !!!"STEP SCAN PROGRAM BY H.R. BALLARD, 11/82"
01.20 A !!"SPECIMEN #",Q5
01.30 A !!"STEP DISTANCE IN MICRONS",D
01.35 A !"DRIVE: X=1, Y=2",Q5
01.36 I (Q5-1)1.37,1.37,1.38
01.37 S D0=D;S D1=0;G 1.4
01.38 S D0=0;S D1=D
01.40 A !"NUMBER OF STEPS",S
01.50 A !"COUNTING TIME IN SECONDS",T;S T=T*10
01.55 A !"NUMBER OF COUNTING PERIODS",C
01.65 A !"ELEMENT NO. CH.1",E1;A "CH.2",E2;A "CH.3",E3
01.67 A !"GRAPH (YES=1,NO=0)"Q3
01.68 I (Q3)1.7,1.7,3.1
01.70 A !"READY",Q2;S GP(Q5)=0
01.75 I (Q3)1.8,1.8,4.1
01.80 T !!"  POS    CURRENT              COUNTS"
01.85 T !"    X       MA      EL#",%2,E1,"    EL#",E2,"    EL#",E3,!!
01.90 S S=S-1;L BON(5);F X=1,S;D 2
01.95 L RBL();L RBL();L RBL()

02.01 C COUNT SUBROUTINE
02.05 S XI(1)=0;S XI(2)=0;S XI(3)=0
02.07 G 2.15
02.10 L MSR(T);S XI(1)=XI(1)+XR(1);S XI(2)=XI(2)+XR(2);S XI(3)=XI(3)+XR(3)
02.15 F Y=1,C;D 2.10
02.17 S XI(1)=XI(1)/C;S XI(2)=XI(2)/C;S XI(3)=XI(3)/C
02.48 I (Q3)3.8,3.8
02.50 I (XI(1)-Y1)2.68;I (Y2-XI(1))2.68;I (XI(2)-Y3)2.68
02.55 I (Y4-XI(2))2.68;I (XI(3)-Y5)2.68;I (Y6-XI(3))2.68
02.65 D 5;D %;G 2.70
02.68 T !,%4,GP(Q5),"+                ERROR"
02.70 L DSG(D0,D1,0)

03.01 C END GRAPH INIT.,PRINT TABLE DATA
03.05 L BOF();T !!!!!;R
03.10 A !"LOWEST Y VALUE CH.1"Y1;A " HIGHEST"Y2
03.20 A !"LOWEST Y VALUE CH.2"Y3;A " HIGHEST"Y4
03.30 A !"LOWEST Y VALUE CH.3"Y5;A " HIGHEST"Y6
03.40 G 1.7
03.80 T %4,GP(Q5),%9,MA/IN,XI(1),XI(2),XI(3);T !;G 2.70

04.01 C PRINT GRAPH HEAD
04.10 T !!!,"EL#",%2,E1,"     1",!;T %5,Y1;F M=1,63;D 6.10
04.20 T %5,Y2
04.30 T !,"EL#",%2,E2,"     2",!;T %5,Y3;F M=1,63;D 6.10
04.40 T %5,Y4
04.50 T !,"EL#",%2,E3,"     3",!;T %5,Y5;F M=1,63;D 6.10
04.60 T %5,Y6
04.70 T !,"      +";F M=1,69;D 6.20
04.80 G 1.9

05.01 C GRAPH RATIO
05.10 S S1=70*((XI(1)-Y1)/(Y2-Y1))
05.20 S S2=70*((XI(2)-Y3)/(Y4-Y3))
05.30 S S3=70*((XI(3)-Y5)/(Y6-Y5))
05.40 S I1=(S1-FITR(S1))*10
05.45 S I2=(S2-FITR(S2))*10
05.50 S I3=(S3-FITR(S3))*10
05.55 I (5-I1)5.7,0,5.75
05.60 I (5-I2)5.80,0,5.85
05.65 I (5-I3)5.90,0,5.95
05.70 S S1=FITR(S1)+1;G 5.6
05.75 S S1=FITR(S1);G 5.6
05.80 S S2=FITR(S2)+1;G 5.65
05.85 S S2=FITR(S2);G 5.65
05.90 S S3=FITR(S3)+1;R
05.95 S S3=FITR(S3);R
```

```
06.10 T " "
06.20 T "+"
06.30 T "-"
06.40 T "1"
06.50 T "2"
06.60 T "3"
06.95 T "X"

07.01 C GRAPH LOGIC
07.10 I (S3-S2)7.2,7.15,7.3
07.15 I (S2-S1)14.35,14.45,14.55
07.20 I (S2-S1)7.4,14.15,7.5
07.30 I (S2-S1)7.6,14.75,7.7
07.40 I (S1-S3)0,0,14.1
07.50 I (S1-S3)14.2,14.25,14.3
07.60 I (S1-S3)14.4,14.65,14.5
07.70 I (S1-S3)14.6,0,0

08.01 C PRINT S1<S2<S3
08.10 D 6.30;T %4,GP(05);D 6.20;F M=1,(S1-1);D 6.10
08.20 D 6.40;F M=1,(S2-S1-1);D 6.10
08.30 D 6.50;F M=1,(S3-S2-1);D 6.10
08.40 D 6.60

09.01 C PRINT S2<S3<S1
09.10 D 6.30;T %4,GP(05);D 6.20;F M=1,(S2-1);D 6.10
09.20 D 6.50;F M=1,(S3-S2-1);D 6.10
09.30 D 6.60;F M=1,(S1-S3-1);D 6.10
09.40 D 6.40

10.01 C PRINT S3<S1<S2
10.10 D 6.30;T %4,GP(05);D 6.20;F M=1,(S3-1);D 6.10
10.20 D 6.60;F M=1,(S1-S3-1);D 6.10
10.30 D 6.40;F M=1,(S2-S1-1);D 6.10
10.40 D 6.50

11.01 C PRINT S1<S3<S2
11.10 D 8.10
11.20 D 6.40;F M=1,(S3-S1-1);D 6.10
11.30 D 6.60;F M=1,(S2-S3-1);D 6.10
11.40 D 6.50

12.01 C PRINT S2<S1<S3
12.10 D 9.10
12.20 D 6.50;F M=1,(S1-S2-1);D 6.10
12.30 D 6.40;F M=1,(S3-S1-1);D 6.10
12.40 D 6.60

13.01 C PRINT S3<S2<S1
13.10 D 10.10
13.20 D 6.60;F M=1,(S2-S3-1);D 6.10
13.30 D 6.50;F M=1,(S1-S2-1);D 6.10
13.40 D 6.40

14.01 C GRAPH X?01.00
#W 14
14.01 C GRAPH X<Y<Z SUB. CALLS
14.10 D 13;R
14.15 D 10.1;D 10.2;D 6.95;R
14.20 D 11;R
14.25 D 8.10;D 6.95;D 14.26;D 14.27
14.26 F M=1,(S2-S1-1);D 6.10
14.27 D 6.5;R
14.30 D 10;R
14.35 D 9.10;D 6.95;D 14.36;D 14.37
14.36 F M=1,(S1-S3-1);D 6.10
14.37 D 6.4;R
14.40 D 12;R
14.45 D 8.1;D 6.95;R
14.50 D 9;R
14.55 D 8.1;D 8.2;D 6.95;R
14.60 D 8;R
14.65 D 9.1;D 9.2;D 6.95;R
14.75 D 8.10;D 6.95;D 14.76;D 14.77
14.76 F M=1,(S3-S2-1);D 6.10
14.77 D 6.6;R
```

FORMULA CALCULATION FROM A MINERAL ANALYSIS II

Source Environment: HP-41C programmable calculator
Installed resources: n.a.

This calculator program was written for use while collecting microprobe data to quickly check mineral fromulas and determine FeO/Fe_2O_3 ratios of oxide minerals. Version I was published in the Hewlett-Packard User's Library, Series 40 Software Catalog in August, 1983. The listing on the following pages is in the format used for program submittal.

PROGRAM SUBMITTAL

☐ New Program ☒ Revision to Program 01212107 1C

Model No. ☐ 67 ☐ 97 ☒ 41

Program Title FORMULA CALCULATION FROM AN ANALYSIS

No. Lines 01516 14 Bytes Category No. 16010 (Primary)

Primary Category Name GEOLOGY

Abstract-75 Word Maximum Program calculates, from oxide weight percent mineral analysis, a chemical formula on the basis of a given number of oxygen atoms. Superior to MINCAL original in that H_2O and Fe_2O_3 are estimated stoichiometrically, making it ideal for electron microprobe analysis data reduction. Also, gram-oxygen units may be calculated from the oxide analysis ~~for~~ facilitating mineralogic comparisons.

Necessary Accessories: At least one memory module for the 41C.

Name Hyram R. Ballard

Company (If Applicable)

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Phone Number ( ) 741-257 Dunedin Country New Zealand

Hewlett Packard Dealer

Acceptance Choice: ☐ FOUR $6.00 PROGRAMS ☒ ONE POINT CERTIFICATE

Please use the checklist below to insure submittal of all proper program documents

☐ SIGNED PROGRAM SUBMITTAL PAGE	☐ Program Description II	☐ Program Listing(s)	☐ Registers, Status...
☐ Program Description I	☐ User Instructions	☐ MASS STORAGE MEDIA	☐ Keyboard, Card Labeling (optional)

ACKNOWLEDGMENT AND AGREEMENT

To the best of my knowledge, I have the right to contribute this program material without breaching any obligation concerning nondisclosure of proprietary or confidential information of other persons or organizations. I am contributing this program material on a nonconfidential nonobligatory basis to Hewlett-Packard Company ("HP") for inclusion in its program library, and I agree that HP may use, duplicate, modify, publish, and sell the program material, and authorize others to do so without obligation or liability of any kind. HP may publish my name and address, as the contributor, to facilitate user inquiries pertaining to this program material.

Signature H.R. Ballard Date

HP USE ONLY	No. Pages:	Mag Cards Cassette:	Price:

PROGRAM DESCRIPTION I

Program Title MINCAL II

Contributor's Name Hyram R. Ballard

Address Dept. of Geology, University of Otago, P.O. Box 56

City Dunedin State/Country New Zealand Zip Code

Program Description, Equations, Variables The program calculates a chemical formula from an oxide wt% analysis. It is superior to MINCAL original in that Fe_2O_3 and water are estimated stoichiometrically. Also, gram-oxygen units may be determined facilitating mineralogic comparisons. "Modular" element subroutines allow rapid insertion or deletion of specific elements to tailor program to user's needs. A useful program for processing microprobe mineral analyses.

Input is prompted and when alpha information is required the program sets the calculator in ALPHA mode

Necessary Accessories Three memory or one quad memory modules

Operating Limits and Warnings Standard accuracy limits of mineral analyses calculated from and formulas calculated from them apply

Reference(s) Deer, Howie, Zussman: An Introduction to the Rock Forming Minerals, Appendices 1 and 2; Longman Group Ltd. London 1966 — Normalisations of Thermodynamic Properties and

Program Description I

(CONTINUATION PAGE)

Some Implications for Graphical and Analytical Problems in Petrology; Brady, John B. and Stout, James H.; American Journal of Science, Vol. 280, Feb. 1980, P. 173-189

The Uncertainty in the Calculated Ferric Iron Content of a Microprobe Analysis; Finger, L.W.; Carnegie Institution Yearbook 71; 1972

The basic calculation of a chemical formula from an oxide weight analysis is explained in Deer, et al. appendix 1 and will not be detailed further.

The calculation of Fe^{3+} and subsequent weight percentages of Fe_2O_3 is performed as a re-calculation of the formula values determined by the program thus:

1) each cation species is normalised to an ideal total

2) then $Fe^{3+} = 2(N_a - \sum_i N_i r_i)$ where N_a = number of anions per mineral formula unit, N_i = number of cations in normalised ideal mineral formula unit, r_i = ratio of oxygen to cations in oxide formula unit e.g. 3/2 for Al_2O_3, 1/2 for Na_2O etc. This equation is valid if all the cations are known and accounted for in the analysis; iron is the only multi-valent ion considered and oxygen is the only anion present.

3) Fe^{2+} = normalised $Fe^{2+} - Fe^{3+}$

4) Weight per cent of FeO and Fe_2O_3 are then calculated using a species of good analysis quality and performing the mineral formula calculations in reverse. To do this information is required to be input by the user and is prompted for. The input prompts after the display CALC OXIDES are:

WT% ⇒ weight per cent of oxide to be used to determine factors for back calculation

Program Description I

(CONTINUATION PAGE)

CAT COEF. ⇒ the value of the cation subscript for the oxide chosen

FORM. WT ⇒ formula weight of the oxide chosen

CAT PROP ⇒ cation value (returned by calculator) in calculated formula.

Weight per cent Fe_2O_3 and FeO are then displayed (see sample problem #2.)

The calculation of gram-oxygen units (see Brady & Stout) is simple as it is basically column 4 in appendix 1 of Deer et al. The components of the gram-oxygen units of the mineral formula are displayed as oxides. Note that at the end of the running of this option the formula cation total is displayed as the gram-oxygen unit total is the anion basis ± 0.002.

Weight percent water is calculated by using factors determined in an anhydrous calculation of the mineral formula and based on the ideal number of hydroxl ions input. The anhydrous oxygen basis is determined by subtracting the oxygen due to water from the mineral formula e.g. in the amphibole actinolite, the formula is: $Ca_2Mg_5Si_8O_{22}(OH)_2$. If H_2O is subtracted from the formula the remaining oxygens are 23 in number. This value may also be derived by summing the oxygens in the component oxides e.g. $2\ CaO = 2.0$, $5\ MgO = 5.0$, $8\ SiO_2 = 16.0$ and $2+5+16 = 23$. (Note some minerals e.g. epidote have non-integer values for anhydrous oxygen) If water has been analytically determined the total anion basis must be input when NO OF AN ? is prompted (for the above amphibole this is 24) and default with R/S when NO OH? is prompted.

Due to the nature of the water estimation calculation, if gram oxygen units are required of a hydrous mineral

(CONTINUATION PAGE)

...it is best to calculate the weight percent water and number of cations in the formula first, then re-input the analysis with estimated H_2O and the gram: oxygen unit subroutine selected.

The data storage registers required by the program are initially cleared by an ISG loop at the beginning of the program. It is important that the number of data registers required are available and that the program can clear them before calculations begin. The number of registers required is: $R = (2 * E) + 7$ where R = number of registers and E = number of element oxides to be input. As supplied, if all 12 element oxides were to be used, $R = (2 * 12) + 7 = 31$ so SIZE must be set at 32. Seldom are all 12 oxides used in one calculation, usually 8 are used so practically SIZE could be set at 24. The number of registers cleared by the "cleaning loop" is set by the value in step 5, this is a four digit, three decimal place number used to control the ISG loop. The last two digits denote the last register to be cleared ie. if 1.031 then registers R_{00} through R_{31} inclusive are cleared. A NONEXISTENT error message will be returned if in 1.0XX, XX is less than SIZE minus one or if more registers are required by the program than have been set by SIZE.

All flags set or cleared by the program are returned to the initial modes set out in the FLAGS section at the end of program operation.

Program Description I

(CONTINUATION PAGE)

Default Conditions (i.e. no input after prompt)

Prompt	default
CALC FE2O3?	No
GM OX UNITS?	No
NO OF AN?	no default allowed
NO OH?	0
OXIDE?	returns OXIDE? to indirect storage register
AGAIN?	No

Oxides available in the program as supplied number 12 and are: SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, H_2O, Cr_2O_3. Other oxides may be made available by installing the appropriate paired subroutines, the four types are listed below:

Type	"X"O	"X"O_2	"X"$_2$O	"X"$_3$O
Subroutine "display"	LBL "X"O →	→	→	→
	XEQ 36	XEQ 34	XEQ 37	XEQ 35
	"X" →	→	→	→
	XEQ 14	XEQ 11	XEQ 13	XEQ 12
	XEQ 40	XEQ 38	XEQ 41	XEQ 39
	XEQ 07 →	→		RTN
	RTN →	→		
"formula"	LBL "X" →	→	→	→
	RDN →	→	→	→
	formula weight →	→	→	→
	/ →	→	→	→
	XEQ 02	2	XEQ 02	3
	RTN	*	RTN	*
		XEQ 02		XEQ 02
		RTN		RTN

To install subroutines position program to first subroutine in display sequence using the CATALOG function, BST once then input the appropriate display steps, and formula steps. There is no necessary sequencing of sub-routines i.e. they need not be paired with respect to the position in the subroutine "library" or in any particular sequence in the "library".

Program Description I

(CONTINUATION PAGE)

Choose mnemonics ("X"'s above) carefully so as not to confuse the calculator with local ALPHA labels. Also the "X" used above will be used to append the appropriate ALPHA string to in gram-oxygen unit mode and will represent the cation ALPHA string as values are returned. The only two mnemonics in the supplied program which are not obvious are FE2 for Fe_2O_3 (and therefore Fe^{3+}) and H2 for H_2O (and therefore OH).

If the program is loaded by hand it will be "uncompiled" and the first run through will be very slow, and program execution errors may occur - ignore these and continue inputting data when required - the next run will be much faster and work smoothly

PROGRAM DESCRIPTION II

Sample Problem (Sketch if Desired)

#1. Given a clinopyroxene analysis, calculate the mineral formula and component gram-oxygen units

CPX		Mnemonic	Solution formula	Solution gram-oxygen units
SiO_2	51.30	SI	Si = 1.902	SiO_2 = 3.805
Al_2O_3	3.10	AL	Al = 0.136	Al_2O_3 = 0.203
TiO_2	0.32	TI	Ti = 0.009	TiO_2 = 0.018
FeO	7.41	FE	Fe^{+2} = 0.230	FeO = 0.230
MgO	15.47	MG	Mg = 0.855	MgO = 0.855
CaO	21.46	CA	Ca = 0.853	CaO = 0.853
Cr_2O_3	0.84	CR	Cr = 0.025	CrO = 0.037
	99.92		total 4.009	

Anion basis = 6

SOLUTION:

Display	Input	Function	Comments
		[XEQ] MINCAL2	Begin program
CALC FE2O3?		[R/S]	Default Fe_2O_3 option
GM. OX. UNITS?		[R/S]	Default gram-oxygen units option
NO. OF AN?	6	[R/S]	Input anion basis
NO. OH?		[R/S]	Default H_2O option
OXIDE?	SI	[R/S]	Input oxide mnemonic
WT%?	51.30	[R/S]	Input weight percent of above oxide
OXIDE?	AL	↓	Continue until all oxides and weight percents input
↓	↓	↓	↓
OXIDE?	CR	[R/S]	
WT%?	0.84	[R/S]	
OXIDE?		[R/S]	Advance program
WT%?		[C]	Calculate
SI = 1.902		[R/S]	Si cations in formula
AL = 0.136		[R/S]	Al cations in formula etc
↓		↓	↓
CR = 0.025		[R/S]	
Σ CAT. = 4.009		[R/S]	Cation total
AGAIN?	Y	[R/S]	Run program again
CALC FE2O3?	Y	[R/S]	as above
GM. OX. UNITS?	Y	[R/S]	Select gram oxygen units option
NO. OF AN?	6	[R/S]	as above. Continue as above
↓	↓	↓	
OXIDE?		[R/S]	Advance program
WT%		[C]	Calculate
SIO2 = 3.805		[R/S]	Gram oxygen units of SIO2
↓		↓	↓
Σ CAT. = 4.009		[R/S]	Cation total (NOT! gram oxygen total)
AGAIN?		[R/S]	Default run-again option

PROGRAM DESCRIPTION II

Sample Problem (Sketch if Desired)

#2 Chromite analysis calculate mineral formula with Fe_2O_3 estimated

		Solution	New total oxides due to calculated Fe_2O_3
MgO	14.3	$Mg = 0.683$	$97.06 - 32.1$
Al_2O_3	13.8	$Al = 0.521$	$+ 22.04 + 12.25$
SiO_2	0.39	$Si = 0.012$	$= 99.25$
TiO_2	0.22	$Ti = 0.005$	
Cr_2O_3	36.0	$Cr = 0.912$	
MnO	0.25	$Mn = 0.007$	
FeO	32.1	$Fe^{+2} = 0.328$	
	97.06	$Fe^{+3} = 0.532$	
			3.000

Anion basis = 4
Ideal cation total = 3

SOLUTION:

Display	Input	Function	Comments
		[XEQ] MINCAL 2	Begin program
CALC FE2O3?	Y	[R/S]	Fe_2O_3 option taken
GM OX. UNITS?	↵	[R/S]	Default gram-oxygen units option
NO. OF AN?	4	[R/S]	Input anion basis
NO. OH?		[R/S]	Default H_2O option
OXIDE?	MG	[R/S]	Input oxide mnemonic
WT%	14.3	[R/S]	Input weight percent of oxide above
↓	↓	↓	Continue until all data entered
OXIDE?		[R/S]	Advance program
WT%?		[C]	Calculate
IDEAL CAT Σ?	3	[R/S]	Input ideal cation total
MG = 4.779 0.683		[R/S]	Mg cations in formula
AL = 0.521		[R/S]	Al cations in formula
↓		↓	↓
FE+2 = 0.328		[R/S]	Fe^{+2} cations in formula
FE+3 = 0.532		[R/S]	Fe^{+3} cations in formula
CALC OXIDES			Next inputs for calculating iron oxides weight per cent.
WT%	36.0	[R/S]	Using Cr_2O_3 to "back-calculate"
COEF.	2	[R/S]	subscript of Cr_2O_3
FORM. WT.	152.02	[R/S]	Formula weight of Cr_2O_3
CAT. PROP.	0.912	[R/S]	Cation proportion in formula of Cr_2O_3
FE2O3 = 22.045		[R/S]	Weight percent of Fe_2O_3
FEO = 12.251		[R/S]	Weight percent of FeO
AGAIN?		[R/S]	Default run again option

PROGRAM DESCRIPTION II

Sample Problem (Sketch if Desired)

#3 Calculate mineral formula and estimate weight percent water in actinolite

		Solution	
SiO_2	54.64	Si = 7.725	WT% H_2O = 2.121
Al_2O_3	3.69	Al = 0.615	+98.33
FeO	11.41	Fe^{+2} = 1.349	100.45% total wt% oxides.
MgO	15.95	Mg = 3.361	
CaO	12.48	Ca = 1.891	
Cr_2O_3	0.16	Cr = 0.018	
	98.33	14.958 + 2(OH)	
		= 16.958	

Anion basis (anhydrous) = 23

Hydroxls = 2

SOLUTION:

Display	Input	Function	Comments
		[XEQ] MINCAL2	Begin program
CALC FE2O3?		[R/S]	Default Fe_2O_3 option
GM OR UNITS?		[R/S]	Default gram = oxygen units option
NO OF AN?	23	[R/S]	Input anhydrous anion basis
NO OH?	2	[R/S]	Input number of hydroxls in formula
OXIDE?	SI	[R/S]	Input oxide mnemonic
WT%	54.64	[R/S]	Input weight percent oxide for above
↓	↓	↓	↓
OXIDE?		[R/S]	Advance program
WT%?		[C]	Calculate
SI = 7.725		[R/S]	Si cations in formula
↓	↓	↓	↓
ΣCAT. = 14.958		[R/S]	Cation total
%H_2O = 2.121		[R/S]	Weight percent H_2O calculated
AGAIN?		[R/S]	Default run-again option.

USER INSTRUCTIONS

SIZE: (2*E)+7+1 (HP-41C)

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1.	Enter program, set size			
2.	Run program		[XEQ] MIN	CALC FE2O3?
3.	Calculate Fe_2O_3 option? ~~Y option~~	Y or N	[Y] or [N] [R/S]	GM. OX. UNITS?
4.	Return mineral formula in gram-oxygen units?	Y or N	[Y] or [N] [R/S]	NO. OF AN?
5.	Input number of anions. 1) If H_2O to be calculated use 2) If H_2O previously determined anhydrous value, use total anions (O+OH)	A	[R/S]	NO. OH?
6	Input number of hydroxls or option 2 above (default if nil)	OH or nil	[R/S]	OXIDE?
6&7	Begin input of oxide mnemonics and wt%s	"SI"	[R/S]	WT%?
	continue until all values input	SI%	[R/S]	OXIDE?
8.	Advance program once		[R/S]	WT%?
9.	Begin calculation		[C]	
10	Return mineral formula values continue			SI = value
	with R/S until all values returned		[R/S]	Σ CAT = value
	If option 2 in 5 above		[R/S]	$\%H_2O$ = value
or			[R/S]	
10	If option Y in 3 above			IDEAL CATΣ?
	Input ideal cation total	C_T	[R/S]	cation = value
	Return mineral formula values continue			
	with R/S until all values returned		[R/S]	CALC OXIDES WT%
	Next routine for calculating appropriate new values for FeO, Fe_2O_3. Input weight% of chosen oxide	value	[R/S]	CAT. COEF.
	to "back calculate". Input cation subscript of oxide	value	[R/S]	FORM. WT.
	Input formula weight of chosen oxide	value	[R/S]	CAT. PROP.
	Input determined mineral formula value	value	[R/S]	FE2O3 = value
	Value of Fe_2O_3 weight per-cent returned		[R/S]	FEO = value
	Value of FeO weight per-cent returned		[R/S]	

USER INSTRUCTIONS

STEP	INSTRUCTIONS	INPUT	FUNCTION	SIZE: (HP-41C) DISPLAY
目			[R/S]	AGAIN?
11	To begin a new calculation Y else N	Y or N	[R/S]	If Y CALC FE203? If N 0.000
	Note: Y option in 4 above does not alter any routines but only gives different output values in oxide (e.g SIO2) rather than cation (eg SI) format.			

PROGRAM LISTING

☐ 67 ☐ 97 ☒ 41C

STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
01	LBL MIN		
	SF 27		
	SF 21		
	CLST		
05	1.031		"cleaning loop control value
	STO 00		
	LBL 00		cleaning loop
	Ø		
	STO IND 00		
10	ISG 00		
	GTO 00		
	7		
	STO 00		
	8		
	STO 01		
	T CALC FE2O3?		set flags for Fe_2O_3 option
	XEQ 21		
	X=Y?		
	SF 02		
20	T GM. OX. UNITS?		set flags for grom- oxygen units option
	XEQ 21		
	X=Y?		
	SF 00		
	T NO. OF AN?		Input anion bars
	PROMPT		
	STO 02		
	STO 06		
	CLX		Set flags, input number of OH
	T NO. OH?		
30	PROMPT		
	9.008		
	*		
	STO 05		
	X=Ø?		
	GTO 01		
	SF 01		
	LBL 01		Data input loop
	T OXIDE?		
	AON		
40	PROMPT		
	ASTO IND 00		
	AOFF		
	WT%?		
	PROMPT		
	RCL IND 00		
	XEQ IND X		
	GTO 01		
	LBL 34		
	FS? 03		
50	GTO 25		

STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
51	RTN		Labels to control branching according to whether oxide is "x"O, "x"O_2 "x"$_2O_3$, "x"$_2O$
	LBL 35		
	FS? 03		
	GTO 26		
	RTN		
	LBL 36		
	FS? 03		
	GTO 27		
	RTN		
60	LBL 37		
	FS? 03		
	GTO 28		
	RTN		
	LBL 38		
	FS? 00		
	XEQ 16		
	RTN		
	LBL 39		
	FS? 00		
70	XEQ 17		
	RTN		
	LBL 40		
	FS? 00		
	XEQ 19		
	RTN		
	LBL 41		
	FS? 00		
	XEQ 18		
	RTN		
80	LBL SID		"Display" subroutines "library"
	XEQ 34		
	T SI		
	XEQ 11		
	XEQ 38		
	XEQ 07		
	RTN		
	LBL TID		
	XEQ 34		
	T TI		
90	XEQ 11		
	XEQ 38		
	XEQ 07		
	RTN		
	LBL ALD		
	XEQ 35		
	T AL		
	XEQ 12		
	XEQ 39		
	XEQ 07		
100	RTN		

Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

PROGRAM LISTING

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STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
101	LBL FE2O		
	T FE		
	XEQ 12		
	XEQ 39		
	FC? 00		
	I +3		
	XEQ 07		
	RTN		
	LBL FED		
110	XEQ 36		
	FE		
	XEQ 14		
	FS? 02		
	GTO 46		
	FC? 04		
	GTO 46		
	RCL IND 03		
	-		
	FS? 04		
120	STO 02		
	LBL 46		Calculation and display controls for Fe_2O_3 option
	XEQ 40		
	FC? 00		
	I +2		
	XEQ 07		
	FS? 04		
	XEQ 47		
	RTN		
	LBL 47		
130	RCL IND 03		
	T FE		
	XEQ 39		
	FC? 00		
	I +3		
	XEQ 07		
	RCL IND 03		
	-		
	RTN		
	LBL MND		
140	XEQ 36		
	MN		
	XEQ 14		
	XEQ 40		
	XEQ 07		
	RTN		
	LBL M6D		
	XEQ 36		
	M6		
	XEQ 14		
150	XEQ 40		

STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
151	XEQ 07		
	RTN		
	LBL CAD		
	XEQ 36		
	T CA		
	XEQ 14		
	XEQ 40		
	XEQ 07		
	RTN		
160	LBL NAD		
	XEQ 37		
	T NA		
	XEQ 13		
	XEQ 41		
	XEQ 07		
	RTN		
	LBL KD		
	XEQ 37		
	T K		
170	XEQ 13		
	XEQ 41		
	XEQ 07		
	RTN		
	LBL H2D		
	XEQ 37		
	T H		
	XEQ 13		
	XEQ 41		
	FC? 00		
180	T OH		
	XEQ 07		
	RTN		
	LBL CRD		
	XEQ 35		
	T CR		
	XEQ 12		
	XEQ 39		
	XEQ 07		
	RTN		
190	LBL 11		Calculations based on oxide type cation/anion ratios
	XEQ 06		
	FS? 04		
	RTN		
	2		
	/		
	ST +02		
	RTN		
	LBL 12		
	XEQ 06		
200	FS? 04		

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PROGRAM LISTING

☐ 67 ☐ 97 ☒ 41C

STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
201	RTN		
	2		
	*		
	3		
	/		
	ST+02		
	RTN		
	LBL B 13		
	XEQ 06		
210	FS? 04		
	RTN		
	2		
	*		
	ST+02		
	RTN		
	LBL 14		
	XEQ 06		
	FS? 04		
	RTN		
220	ST+02		
	RTN		
	LBL 16		Calculate gram-oxygen units from carbon numbers and append ALPHA string for display
	FS? 02		
	RTN		
	2		
	*		
	+02		
	RTN		
	LBL 17		
230	FS? 02		
	RTN		
	3		
	*		
	2		
	/		
	+203		
	RTN		
	LBL 18		
	FS? 02		
240	RTN		
	2		
	/		
	+20		
	RTN		
	LBL 19		
	FS? 02		
	RTN		
	+0		
	RTN		
250	LBL ST		

STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
251	RDN		"Formula" sub-routines
	60.09		
	/		
	2		
	*		
	XEQ 02		
	RTN		
	LBL AL		
	RDN		
260	101.94		
	/		
	3		
	*		
	XEQ 02		
	RTN		
	LBL TI		
	RDN		
	79.90		
	/		
270	2		
	*		
	XEQ 02		
	RTN		
	LBL FE2		
	RDN		
	159.7		
	/		
	3		
	*		
280	XEQ 02		
	RTN		
	LBL FE		
	RDN		
	71.85		
	/		
	XEQ 02		
	RTN		
	LBL MN		
	RDN		
290	70.94		
	/		
	XEQ 02		
	RTN		
	LBL M6		
	RDN		
	40.32		
	/		
	XEQ 02		
	RTN		
300	LBL CA		

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PROGRAM LISTING

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STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
301	RDN		
	56.08		
	/		
	XEQ 02		
	RTN		
	LBL NA		
	RDN		
	61.982		
	/		
310	XEQ 02		
	RTN		
	LBL K		
	RDN		
	94.20		
	/		
	XEQ 02		
	RTN		
	LBL H2		
	RDN		
320	18.016		
	/		
	XEQ 02		
	RTN		
	LBL CR		
	RDN		
	152.02		
	/		
	3		
	*		
330	XEQ 02		
	RTN		
	LBL 02		
	ST + 03		
	STO IND 01		
	2		
	ST + 00		
	ST + 01		
	RTN		
	LBL 06		
340	RCL 00		
	[redacted] /		
	+		
	RCL IND X		
	2		
	ST + 00		
	RDN		
	RTN		
	LBL 07		Display control
	FS? 02		
350	XEQ 20		

STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
351	FS? 02		
	RTN		
	ŀ =		
	ARCL X		
	AVIEW		
	RTN		
	LBL C		
	RCL 02		
	RCL 03		
360	/		
	STO 02		
	FC? 01		
	GTO 03		
	RCL 05		
	/		
	1/X		
	STO 05		
	LBL 03		
	2		
370	ST - 01		
	RCL 02		
	ST * IND 01		
	8		
	RCL 01		
	X <= Y?		
	GTO 04		
	GTO 03		
	LBL 15		weight % H2O display
	RCL 05		
380	T % H2O		
	XEQ 07		
	RTN		
	LBL 04		
	0		
	STO 02		
	RCL 00		
	STO 03		
	7		
	STO 00		
390	FS? 03		
	RTN		
	FIX 3		
	LBL 05		
	CLA		
	ARCL IND 00		
	T + D		
	ASTO IND 00		
	ASTO X		
	XEQ IND X		
400	RCL 03		

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PROGRAM LISTING

☐ 67 ☐ 97 ☑ 41C

STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
401	RCL 00		
	X=Y?		
	GTO 08		
	GTO 05		
	LBL 08		
	FS? 02		
	GTO 30		
	T ΣCAT.=		
	ARCL 02		
410	AVIEW		
	GTO 50		
	LBL 20		
	RCL 00		
	1		
	−		
	X<>Y		
	STO IND Y		
	RTN		
	LBL 23		
420	RCL 00		
	1		
	+		
	STO 00		
	RCL 02		
	ST * IND Y		
	RDN		
	RCL 03		
	X=Y?		
	GTO 24		
430	GTO 23		
	LBL 29		
	SF 03		
	XEQ 04		
	LBL 22		
	RCL IND 00		
	GTO IND X		
	LBL 30		
	T IDEAL CAT#?		
	PROMPT		
440	RCL 02		
	1		
	STO 02		
	8		
	STO 00		
	LBL 31		
	RCL 02		
	ST * IND 00		
	2		
	ST+00		
450	RCL 03		

STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
451	RCL 00		
	X>Y?		
	GTO 29		
	GTO 31		
	LBL 32		
	RCL 03		
	RCL 00		
	1		
	+		
460	X=Y?		
	GTO 33		
	GTO 22		
	LBL 25		
	XEQ 06		
	2		
	*		
	ST+02		
	GTO 32		
	LBL 26		
470	XEQ 06		
	3		
	*		
	2		
	1		
	ST+02		
	GTO 32		
	LBL 27		
	XEQ 06		
	ST+02		
480	GTO 32		
	LBL 28		
	XEQ 06		
	2		
	1		
	ST+02		
	GTO 32		
	LBL 33		
	RCL 06		
	RCL 02		
490	−		
	2		
	*		
	ST IND 03		
	SF 04		
	CF 02		
	CF 03		
	7		
	STO 00		
	LBL 49		
500	RCL IND 00		

Note: Refer to "HP-41C OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for specific information on keystrokes. The Function Index is found at the very back of the Handbook. Refer to Appendix E in 67 or 97 "OWNER'S HANDBOOK AND PROGRAMMING GUIDE" for exact keystrokes.

PROGRAM LISTING

☐ 67 ☐ 97 ☑ 41C

STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS	STEP/ LINE	KEY ENTRY	KEY CODE (67/97 only)	COMMENTS
501	XEQ IND X			551	X=Y?		
	RCL 03				GTO MIN		
	1				CLX		
	−				CLA		
	RCL 00				GTO 99		
	X=Y?				LBL 21		
	GTO 48				AON		
	GTO 49				PROMPT		
	LBL 48				ASTO X		
510	T CALC OXIDES			560	Y		
	CF 21				ASTO Y		
	AVIEW				AOFF		
	PSE				LBL 99		
	SF 21				END		
	T WT%						
	PROMPT						
	T CAT. COEF.						
	PROMPT						
	*						
520	T FORM. WT.			70			
	PROMPT						
	T CAT. PROP.						
	PROMPT						
	*						
	/						
	ENTER↑						
	ENTER↑						
	RCL IND 03						
	159.7						
530	*			80			
	*						
	2						
	/						
	T FE203						
	XEQ 07						
	RDN						
	RCL 02						
	71.85						
	*						
540	*			90			
	T FEO						
	XEQ 07						
	LBL 50						
	FS? C 01						
	XEQ 15						
	CF 00						
	CF 04						
	CF 21						
	T AGAIN?						
550	XEQ 21			00			

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APPENDIX 4
CRYSTALLISATION MODELLING DISCUSSION

Petrologic modelling to determine possible products of an evolving magma are generally of two types, mass balance mixing models and thermodynamic or quasi-thermodynamic crystallisation models. Mass balance mixing models basically solve for the coefficients of the equation:

a*A + **b***B + ...**n***N + **x***less evolved rock = **y***more evolved rock

where A,B,...N are phases of known or estimated composition and **a**, **b**,...**n** are vector coefficients.

If the number of phases is one or two a graphical solution (fig. A4-1) may be obtained by projecting compositions from all components into a plane defined by the ratios of two selected components and all other components. If three or more phases are involved a locus of solutions is generated for each composition plane. To determine the "best fit" solution a numerical model may be employed. This is generally a least-squares algorithm which maps bulk compositions from the higher order (component) space to a lower order (phase) space.

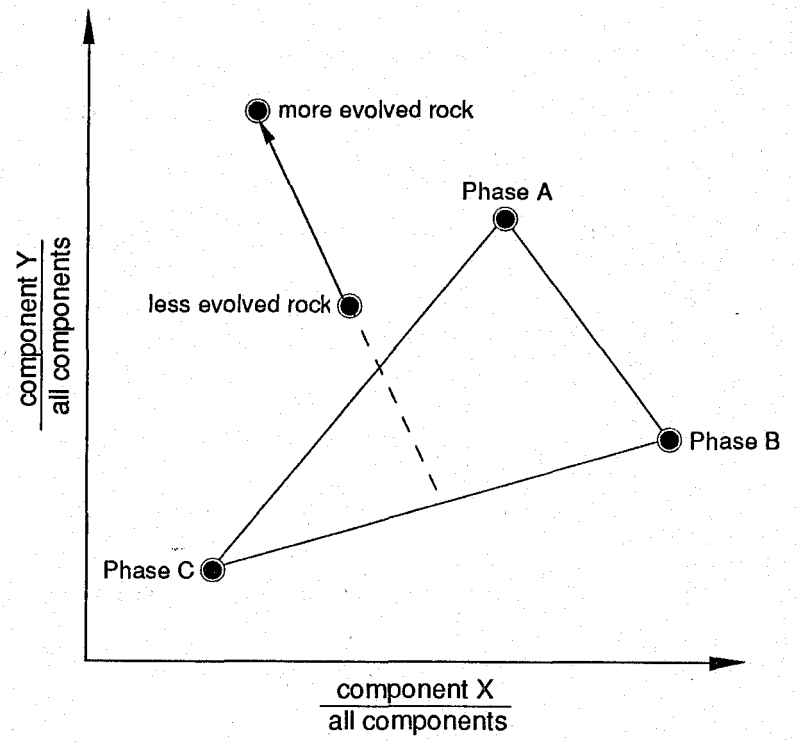

FIGURE A4-1 Graphical representation of a mixing model between two rocks related by a mixture of the less evolved rock and three phases.

Graphical or numerical mixing models require that all compositions be known or well constrained as even small errors can drastically change phase proportion estimates by altering the shape of the "phase volume". Numerical "least-squares" mixing models are also dependent on the formulation of the model due to the non-commutative nature of matrix multiplication.

Quasi-thermodynamic models use a combination of thermodynamic theory and empirical relationships derived from experimental data. This is the method used by Nielsen (1985) on which the algorithms in the computer program EQUIL are based. The thermodynamic basis is as follows:

- For any mineral-melt crystallisation reaction, equilibrium is attained when:

$$\Delta G^\circ = -RT\ln K$$

- At constant pressure, this reduces to:

$$-RT\ln K = \Delta H^\circ - T\Delta S^\circ$$

- Re-arranging:

$$\ln K = \frac{-\Delta H^\circ}{R} * \frac{1}{T} + \frac{\Delta S^\circ}{R}$$

- Since **K**, ΔH° and ΔS° are constants, the equation has the form:

$$\ln K = a * \frac{1}{T} + b$$

$$\text{where} \quad a = \frac{-\Delta H^\circ}{R} \qquad b = \frac{\Delta S^\circ}{R}$$

- Equilibrium reactions define equilibrium constants of the form:

$$K = \frac{\prod P_i^n}{\prod R_i^n}$$

- where $\mathbf{P_i}$ and $\mathbf{R_i}$ denote the activity of product and reactant components and **n** is the stoichiometric molar balance coefficient, e.g. forsterite:

$$2MgO + SiO_2 = Mg_2SiO_4$$

$$K = \left(\frac{a_{Mg_2SiO_4}}{a_{SiO_2} * a^2_{MgO}} \right)$$

- Distribution coefficients are used to approximate equilibrium constants where activities are poorly known so that:

$$\ln K_D = a * \frac{1}{T} + b$$

$$\ln\left(\frac{\prod P_i^n}{\prod R_i^n}\right) = a * \frac{1}{T} + b$$

- This linear correlation between mineral-melt distribution coefficients (K_D) and inverse temperature allows **a** and **b** to be determined as the slope and intercept of a regression line through an experimental data set.

- With these values determined there exists a simple relationship between melt activities, which can be determined from the composition of the liquid, phase composition and temperature.

- As solid solutions are nearly ideal, i.e. there is linear relationship between composition and activity, it is possible to use the equations for the end-members and stoichiometry to determine crystallisation temperature and total solid composition from a given melt composition.
- Using olivine as an example:

$$2\ {}^{l}MgO + {}^{l}SiO_2 = {}^{s}Mg_2SiO_4 = X_{Fo}$$
$$2\ {}^{l}FeO + {}^{l}SiO_2 = {}^{s}Fe_2SiO_4 = X_{Fa}$$
$$X_{Fo} + X_{Fa} = \frac{2}{3}$$

where **X** is in terms of cation mol fraction units.

$$\ln\left(\frac{a_{Mg_2SiO_4}}{a_{SiO_2} * a^2_{MgO}}\right) = a * \frac{1}{T} + b$$

- Since the activity of a pure solid in a mixture is equal to the mol fraction:

$$X_{Fo} = \exp\left(a * \frac{1}{T} + b\right) * \left(a_{SiO_2} * a^2_{MgO}\right) \quad X_{Fo} = f(T)$$
$$X_{Fa} = \exp\left(a * \frac{1}{T} + b\right) * \left(a_{SiO_2} * a^2_{FeO}\right) \quad X_{Fa} = f(T)$$

- As **X** is an exponential function of **T**, this set of equations must be solved numerically, generally by iteration on **T**.

- Using reasonable starting values for **T** and the initial interval, say 1500°K and 50°, an interval halving iteration routine will converge on **T** with a precision of ±0.005° in about 15 passes. For more complex phases, e.g. clinopyroxene, this takes about 30 passes.

To determine the liquid path and composition of the crystallising solids, it is assumed that the phase with the highest determined temperature is on the liquidus surface. Numerically removing a small amount of the crystallising phase from the liquid composition to produce a new liquid and using this new liquid composition in the next calculation it is possible to simulate the liquidus surface in a stepwise fashion (fig. 4-2). Summing the compositions of the solid in each successive removal models a fractional crystallisation situation.

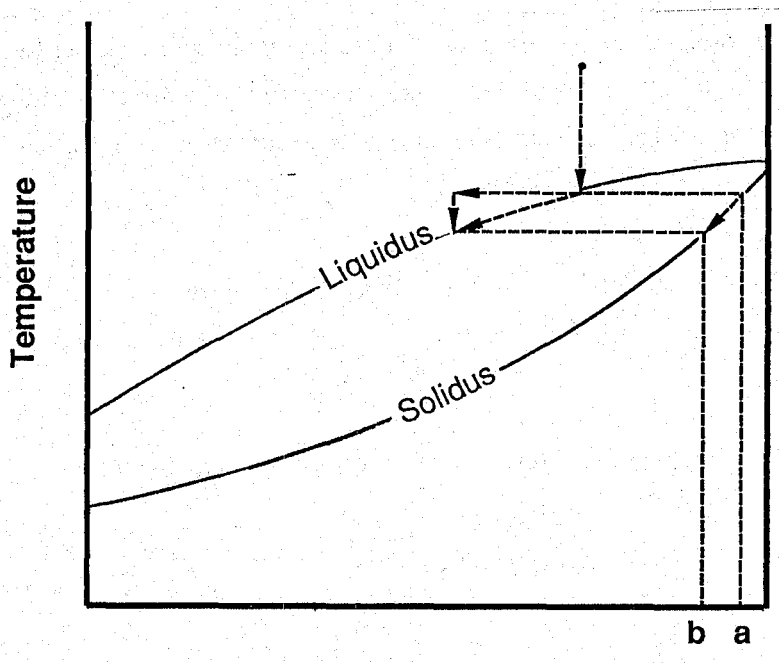

FIGURE A4-2 Hypothetical binary system phase diagram. By removing a small amount of the crystallising phase "a" from the liquid the liquid composition is shifted slightly to the left. The composition of the crystallising phase from this new liquid composition is "b". If the "liquid shift" is small, the liquidus surface will be approximated in a stepwise fashion.

APPENDIX 5
PUBLICATIONS AND PRESENTED PAPERS

Begg, J.G. and Ballard, H.R. – 1989

An Early Permian fauna from the Brook Street Terrane, Skippers Range, northwest Otago.
submitted in March to New Zealand journal of geology and geophysics.

Ballard, H.R. – 1987

Tholeiitic arc-ankaramites in the Permian Brook Street Terrane: possible primary melts?
Geological Society of New Zealand misc. publication, 37A
Presented at Geological Society annual conference, Dunedin, December 1987

Ballard, H.R. – 1986

Tholeiitic ankaramite volcanism in the Permian island-arc Brook Street Terrane of New Zealand.
Presented at International Volcanological Congress, Auckland-Hamilton-Rotorua, February 1986

Begg, J.G. and Ballard, H.R. – 1985

The first *Eurydesma* fauna from New Zealand, its correlation and depositional environment.
New Zealand Geological Survey, Record 9, p. 14-15
Presented by J.G. Begg at Hornibrook Symposium, Christchurch, December 1985

Ballard, H.R. – 1983

Reconnaissance geology of Brook Street volcanic rocks adjacent to the southeastern side of the Alpine Fault, New Zealand.
Presented in Students Section, Pacific Science Association 15th Congress, Dunedin, February 1983

AN EARLY PERMIAN FAUNA FROM BROOK STREET TERRANE, SKIPPERS RANGE, NORTHWEST OTAGO.

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University of Otago
PO Box 56
Dunedin.

Abstract: The Mantle Volcanics Formation of the Brook Street Terrane, Skippers Range, is characterised by volcaniclastic sediments and hypabyssal intrusions interpreted as having accumulated in the immediate vicinity of an island volcano(s). Sedimentological evidence indicates that much of the sediment was deposited from debris flows which were associated with traction and turbidity currents.

An Early Permian fauna from the formation is described and correlated with others in New Zealand and east Australia. The fauna includes the first New Zealand record of the cool-cold water, Gondwanan bivalve family Eurydesmidae; this and other bivalves, gastropods, brachiopods, Bryozoa, rugosans and echinoderms are described.

Keywords: paleontology; Brachiopoda; Bivalvia; Gastropoda; Eurydesmidae; Early Permian; Skippers Range; Mantle Volcanics Formation; New Zealand/east Australian correlation; paleoecology, Brook Street Terrane; NZMS 260 Sheet D 39.

Introduction

Permian volcaniclastic and hypabyssal rocks which crop out in the Skippers Range, northwest Otago, have been studied by Grindley (1958), Wood (1962), Mutch (1964), Mutch and McKellar (1964), Carmen (1968) and Nauman (1973). They most closely resemble rocks of the Eglinton Volcanics (north-west Otago) which are of a similar age. Other early Permian volcanic rocks of New Zealand include the Takitimu Group

(western Southland) and Brook Street Volcanics (Nelson). These bodies of rock form part of a discontinuous belt(s) of volcanigenic and intrusive rocks included within the Brook Street Terrane.

Nauman (1973) named the volcaniclastic and hypabyssal rocks of the southern Skippers Range (south of Hokuri Creek) Mantle Volcanics Formation, and work in progress by Ballard indicates its continuation into the northern part of the range (Fig. 1). Williams and Smith (1979) demonstrated that the Eglinton Volcanics in the Eglinton Valley is composed of two distinct suites, the Plato and the Largs terranes, characterised by primitive island-arc tholeiites and more evolved andesitic to dacitic rocks respectively. The Mantle Volcanics Formation is lithologically and geochemically similar (Ballard, work in progress) to the Gondor Formation (Williams 1978) of the Plato terrane.

Stratigraphy and Sedimentology

The Mantle Volcanics Formation is a >1300 m (base unexposed) pile of gently to moderately southwest dipping suite of pyroclastic and first cycle epiclastic sediments intruded by dykes, sills and small stocks. Intrusives which make up approximately 30% of the total rock volume are characterised by ankaramites with clinopyroxene megacrysts. In places, tuffs have been intruded while still plastic, forming peperites. Sediments consist of crystal-lithic tuffs, lapilli tuffs, tuffaceous breccias and conglomerates. There is a rough correlation between clast size and bed thickness, with coarse grained (clast size >10mm) clastic, pyroclastic and tuffaceous breccias predominant and forming beds often in excess of 1 m. The sediments are well stratified, although individual beds may be laterally discontinuous over distances of a few tens of metres owing to depositional lensing or erosional scouring by younger units.

The regional dip direction is to the southwest (180° to 280°) with dips from 10° to 44°. Locally variation in attitude is due to rotation by small-displacement faults and detachment of sediment screens between dykes, but variation may in part be depositional.

Coarse clastic beds are poorly sorted to unsorted (sorting terminology after Jones 1967) with weak to moderate inverse grading through

individual beds, and with large clasts projecting into overlying beds. Clast roundness is subangular to subrounded, except for one bed which consists of very well rounded boulders which are nearly exclusively ankaramitic. Conglomerate and tuffaceous breccia clasts are normally basaltic and are nearly all of the same composition as the intrusives. Some clasts are oxidised to red and purple colours and some are bomb-like in shape.

Tuffs are crystal-lithic (often clinopyroxene-rich), of very fine to coarse sand size, and may incorporate lapilli. Normal grading, trough stratification and local isolated outsized clasts and/or pebble "trains" are common. Ripple laminations and mantling silts are less common. Cross-stratified beds range from 10 to 50 cm in thickness, with steeply dipping foresets, some of which may be traced 2m laterally. These finer sediments are well sorted, excluding outsized clasts, and often occur at the top of abruptly upward fining sequences of coarse tuffaceous breccias in which grading occurs over a thickness of a few centimetres.

The thick-bedded, extremely coarse tuffaceous breccia units with inverse grading and upward projecting clasts indicate a debris flow depositional mechanism (Fisher 1971; Middleton and Hampton 1973; Walker 1975). Normal grading, pebble "trains", ramping of sediment onto outsized clasts and other traction features within overlying tuffaceous strata imply deposition from high density turbidity currents with occasional modification of bedforms by residual currents to form large scale cross-stratification, ripple laminations and other features as described by Lowe (1982). The abrupt upward fining of the debris flow units to well sorted medium-coarse sand grade tuffs, many of which are cross-stratified, suggests an association of turbidity currents with the debris flows. Turbidity currents and debris flow couplets may have been initiated by single events.

Paleontology

Marine Permian fossils were found in talus boulders up to 5m in diameter, shed from the east wall of a cirque basin at the head of the southernmost branch of Wilmot River (D39, GR 249 304 metric overlay on

N.Z.M.S. 1; N.Z. Fossil Record locality D39/f031; Fig. 1). Fossils occur concentrated at the base of thinly bedded basaltic-lithic tuff subsets within bed sets of 1m or greater.

The fossils are preserved as recrystallised calcite in unweathered rock, but are leached to external and internal moulds in weathered rock. Preservation is good, with fine surface features retained on many moulds. The enclosing lithology is typically very fine sand grade clinopyroxene and plagioclase crystal-lithic tuff, with isolated outsized lithic and lapilli clasts up to 20mm in diameter.

Fauna: D39/f031 (Fig. 2-16)

Coelenterata
 Rugosa indet.
Brachiopoda
 Notostrophia cf. homeri Waterhouse
 Lissochonetes cf. yarrolensis Maxwell
 Wyndhamia sp. aff. ingelarensis Dear
 Plekonella sp. indet.
 Aperispirifer crassicostatus Waterhouse?
 Notospirifer sp. (cf. sp. A of Waterhouse 1982a)
 Ingelarella cf. plana Campbell
Bryozoa
 stenoporoid Bryozoa (arborescent and encrusting)
 fenestelloid Bryozoa
Gastropoda
 Pandospira nuda Waterhouse
 Peruvispira robusta Waterhouse
Bivalvia
 Eurydesmidae gen. et sp. indet.
 Etheripecten cf. tenuicollis (Dana)
 Streblopteria sp.
 Squamuliferipecten cf. squamuliferus (Morris)

 C. cf. multicostatus (Fletcher)
Crinoidea
 crinoid calyx with articulated brachials, columnals

Calceospongia sp.
Cidaroida
?archaeocidarid adambulacral plates, spines

Systematics

Phylum Coelenterata
Subclass Rugosa

Rugosa indet.

This subclass is represented in the collection by a single, small (maximum length 34mm; maximum diameter 17mm), nearly complete external mould. It is solitary, slightly curved (ceratoid), longitudinally costate, with the rounded costae occasionally drawn out into low, orally directed spines. Periodic growth rugae indicate an oblique calice. Absence of internal features precludes more accurate identification.

Phylum Brachiopoda
Order Strophomenida Opik
Family Streptorhynchidae Stehli 1954
Genus Notostrophia Waterhouse 1973a
Notostrophia cf. homeri Waterhouse
Fig. 2, 3.

1973a Notostrophia homeri Waterhouse p.36, fig. 1,2.
1982 N. homeri Waterhouse, p26, pl. 3a-h, 4a-d, 5a,d,g; fig.17D.

Material: one specimen only, a pedicle valve, external and internal moulds, with a third of one side missing, external features partly obscured by encrusting stenoporid bryozoan.

Description: external: the valve is cone-shaped and nearly semi-circular in outline; exposed ornament is of rounded radial costae with a density of about 6 per 5mm near the anterior margin; costae increase anteriorly by intercalation. Radial ornament is interrupted by 3 or 4 growth rugae.

Internal: The internal mould shows radial crenulation developed near the anterior margin, high interareas, large blunt teeth, and a

pseudodeltidium which is convex externally. A median septum is lacking, and muscle scars are rounded in outline and centred near one third length.

Remarks: Waterhouse (1982a) distinguished N. homeri from N. zealandicus by a flatter brachial valve which has a median sulcation, reflexed anterior margin, coarser costae and fewer growth rugae.

All features shown by the specimen are consistent with those of most N. homeri paratypes. The holotype of N. homeri displays an apparently recurved brachial valve (see Waterhouse 1982a). Re-examination of the specimen (JGB; G. Thomas pers. comm.) shows that the external of a thickened pedicle valve has been misinterpreted as a "reflexed" part of the brachial valve; differentiation from N. zealandicus proves difficult owing to variation of other distinguishing characteristics in both species. For the purposes of this paper, Waterhouse's two species are synonymised.

Notostrophia was erected for schuchertellids with short, recurved crural plates and differing ornament on brachial and pedicle valves (Waterhouse 1973a). Type specimens of Notostrophia species have socket plates that are not recurved to the posterior hingeline, suggesting placement within the Streptorhynchinae Stehli (emend. Thomas 1958). Other streptorhynchinids include Streptorhynchus King, Kiangsiella Grabau and Chao, and Arctitreta Whitfield (=Grumantia Cernyak; see Stehli and Grant 1971; Manankov 1979). Kiangsiella differs from the others in being plicate. Arctitreta, Streptorhynchus and Notostrophia brachial cardinalia are similar, but the very thick pedicle valve and deeply impressed muscle scars of Notostrophia and Arctitreta distinguish them from Streptorhynchus. Differentiation between Notostrophia and Arctitreta, however, is difficult (G. Thomas pers. comm.).

Family Rugosochonetidae Muir-Wood 1962
Genus Lissochonetes Dunbar and Condra 1932
Lissochonetes cf. yarrolensis Maxwell 1964.
Fig. 4.

1964 Lissochonetes yarrolensis Maxwell p.35, pl.6, figs 9-14.

Material: two double valved externals (one with accompanying internal) and a partial external and complete internal mould of a pedicle valve.

Description: external: Small, concavo-convex, subrectangular to semicircular outline, with a low median fold and laterally elongate valves (width 15mm, length 7.5mm); hingeline is slightly less than maximum width, and cardinal extremities are rounded and obtuse. External moulds show both valves are nearly smooth, with very fine growth lines and extremely fine, hair-like radial spines.

Internal: pedicle internal mould with a well developed median septum and blunt, triangular teeth flanking the lateral margins of the delthyrium; posterior of delthyrium partly infilled with pseudodeltidium. Hinge area moderately high. One specimen displays cardinal endospines, about 7 each side of the beak. The only brachial valve interior is fragmentary and the nature of the median septum and the cardinal process is uncertain, but the right brachial ridge, which curves laterally to converge with the hingeline, is preserved.

Remarks: the determination is based on the small size, concavo-convex subrectangular to semicircular shape, faint concentric ornament and minute spines, strong, triangular teeth and low dental plates, and high pedicle interareas. The specimens are all wider than those figured by Waterhouse (1964, Chonetid gen. et sp. indet., pl.4, fig.1,2, lower Takitimu Group) more closely resembling those figured by Maxwell (1964).

Family Strophalosiidae Schuchert 1913
Genus Wyndhamia Booker 1929
Wyndhamia sp. aff. ingelarensis Dear
Fig. 5, 6.

1971 Wyndhamia ingelarensis Dear p.12, pl. 3, figs 5-10.
1983 Wyndhamia ingelarensis McClung p.73, fig. 14:3-5, 7-8.

Material: a single (?)juvenile brachial valve, internal and external mould.

Description: external: concave, wedge-shaped valve, suboval, slightly wider than long (width 16.5mm, length 12.5mm) with slightly

geniculated anterior margin. The initial juvenile valve form is convex and subquadrate, this becoming concave and suboval at about 7 mm width. Hinge area flat and lying at about 70° to the plane of the first-formed disc. The hingeline is straight and about 3/4 of the length of the shell; the cardinal extremities are bluntly obtuse. The posterior half of the valve is completely smooth, but the anterior half has an ornament of prominent wavey, lamellose concentrics and small, but well developed spines, concentrically arranged.

Internal: the internal mould is characterised by an erect cardinal process (110° to the floor of the disc), a low median septum which terminates near mid-length, and high socket ridges curving from the base of the cardinal process to form a transverse ridge. The sockets are deep and the muscle scars are impressed into the floor of the valve.

Remarks: The specimen shares many features with W. ingelarensis, including the convex shape of the immature brachial valve, dimpled and crinkled ornament, and shape. It differs in that it has sparse, inclined spines arranged in broadly concentric rows.

Neither Maxwell (1954) nor Clarke (1969; see Pseudostrophalosia) illustrated an external or internal brachial valve of W. brittoni, but Maxwell described a moderately concave valve with varying development of growth lamellae and spines. Though smaller, our specimen is similar to that species in its shape, spiney brachial ornament and erect cardinal process, but differs in its immature convexity.

Family Wellerellidae Likharev 1956
Genus Plekonella Campbell 1953
Plekonella sp. indet.
(see Fig. 16).

Material: external moulds only of four fragmentary double-valved specimens, and two disarticulated pedicle and two brachial valves.

Description: pedicle valves are small (5 to 7mm long), subtriangular in outline with high, straight to slightly concave posterior walls; each valve has 8 to 11 high, triangular costae crossed by occasional

conspicuous growth rugae. Umbonal angles are about 70° to 80° and height/width ratios about 0.8:1 to 0.95:1. No internal features are preserved.

Remarks: the specimens cannot be identified to specific level. It is unlikely that they belong to P. campbelli Waterhouse because of the height/width ratios; shape and costal number are more consistent with P. acuta Campbell, a species known from the same stratigraphic horizon elsewhere.

Family Spiriferidae King 1846
Genus Aperispirifer Waterhouse 1968
Aperispirifer crassicostatus Waterhouse?
Fig. 7.

1983 Aperispirifer crassicostatus Waterhouse p.158-9, pl.1, figs 5, 7-10; pl. 2, figs 1,4.

Material: internal and external moulds of four fragmentary double valved specimens and of a juvenile brachial valve.

Description: pedicle external: valve medium sized (half width 18mm, length 28 mm), inflated, sub-semicircular in outline (length/width ratio about 1:1.3) with hinge about 0.8 times width; cardinal extremities rounded, hingeline forming an angle of 100° with the lateral margin. Narrow, moderately deep sulcation but obscure lateral plications. Ornament of high, rounded costae which are faintly fasciculate with intercalated secondaries and reticulated with closely spaced concentric growth lines; four marked concentric rugae. Cardinal area concave and longitudinally striate.

Pedicle internal: teeth supported by triangular dental plates and adminicula; delthyrium open, with a dental callosity and lateral ridges extending anteriorly along the junction of the adminicula and dental plates; a very low dividing ridge separates the muscle fields beneath the delthyrium.

Brachial external: moderately inflated with posterior margin long, hinge straight; cardinal extremities rounded, maximum width near

posterior fifth; valve wider than long (estimated width 16mm, length 11.5mm) with a low median fold. Radial ornament of coarse, high, rounded costae of 2 orders; primaries increase by division into 3, the primary itself continuing unaffected in size, the smaller secondaries added one on each side of the primary; the result is fasciculation over the anterior part of the valve; the median pair of costae divide only on their lateral sides; approximately 35 costae at 6mm from umbo. Intercostal troughs, and possibly crests as well, are finely capillate. Strong, regular concentric lamellae intersect radials (3/mm at 10mm from the umbo).

Brachial internal: wide, shallow sockets flank a broad, longitudinally grooved cardinal process; the median septum is a faint, raised line 1/3rd the length of the valve.

Remarks: the pedicle external is insufficiently preserved and the brachial valve is too immature to be confident of the determination. The specimens differ from the holotype in having rounded cardinal extremities, although some from Queensland (Waterhouse 1983, pl. 1, fig. 5,8,9) apparently are similar. The holotype and other figured specimens have the same high length/width ratio. The costae are similar in number and density to, but higher and more tightly rounded in section than, those of the holotype. The Queensland specimens (Waterhouse 1983; pl. 1, fig. 5,8,9) have fewer, less tightly rounded, more fasciculate costae.

Superfamily Martiniacea Waagen 1883
Family uncertain (see McClung 1978)
Subfamily Ingelarellinae Campbell 1959
Genus Notospirifer Harrington 1955
Notospirifer sp. (cf. sp. A of Waterhouse 1982a)

1982 Notospirifer sp. A Waterhouse, p.57, pl. 15i.

Material: Four specimens; internal and external moulds of a mature pedicle valve, a partial external mould of a mature brachial valve, a mature double valved specimen, and internal and external moulds of a juvenile double valved specimen.

Description: small (width of widest valve 19.5mm), pedicle valve more convex than brachial, outline moderately transverse (length/width ratio about 1:1.5), cardinal extremities obtusely angled (140°); hinge about 2/3rds valve width. Pedicle valve with a deep, rounded, median sulcation and 4 steep-sided plicae on each side. Micro-ornament consists of radially elongate grooves ending in pits and short spine bases terminating in fine spines.

Internal: the pedicle valve has a high concave hinge area with moderately long, only slightly diverging dental plates (1/5th the length of the valve) and a very low median septum; the brachial valve has a short cardinal process and lacks a median septum, but structure is otherwise obscure.

Remarks: The features preserved are insufficient for positive identification. The shape of the valves, the number and steep profile of the costae are similar to specimens figured by Waterhouse (1982a; pl. 15i, and especially pl. 19i).

Genus Ingelarella Campbell 1959
Ingelarella cf. plana Campbell
Fig. 8.

1960 Ingelarella plana Campbell, p.1112, pl.3, figs 1-4.

Material: a nearly complete internal and partial external mould of a pedicle valve, plus other fragments.

Description: external: large (width 57mm, length 60mm), subovate, with a relatively small umbonal angle (about 100°) and a broad, low, evenly rounded pedicle sulcation; no lateral plicae around the median sulcation. Ornament consists of faint concentric lines, micro-ornament of shallow, closely spaced radially elongate surface grooves arranged in quincunx, with 15 per mm laterally and 6 per mm longitudinally near the anterior margin.

Internal: delthyrium open, with strong, wide teeth; dental plates gently diverging (about 20°), parallel to delthyrium margins and perpendicular to commissural plane; dental plates supported by long

adminicula which diverge from the beak at a low angle (about 20°) and diverge from each other towards the ventral floor (at about 40°). The muscle field is slightly raised anteriorly and posteriorly and is separated from the rest of the valve by low ridges that continue anteriorly from the adminicula, unite in front of the muscle field, and extend forwards as a low medial ridge for a short distance. Muscle field is twice as long as high and subpentagonal in shape; the umbonal cavity is heavily thickened.

Remarks: The specimen is longer in proportion to width than I. plana and has a heavier umbonal callosity but corresponds well in other respects.

Understanding of the genera Tomiopsis Benediktova and Ingelarella Campbell is in a state of flux (Archbold and Thomas 1986). Our specimens lack C-shaped protuberances at the posterior end of micro-ornament grooves (a Tomiopsis-like feature) but Ingelarella is retained in the text in the absence of conclusive evidence to do otherwise.

Phylum Bryozoa

Abundant well preserved fenestellid (see Fig. 12) and stenoporid (arborescent and encrusting (see Fig. 4)) bryozoa are present but no systematic placement has been attempted.

Phylum Mollusca
Class Gastropoda
Superfamily Pleurotomariacea Swainson 1840
?Family Sinuopeidae Wenz 1938
Genus Pandospira Waterhouse 1963
Pandospira nuda Waterhouse
Fig. 9, 10.

1963 Pandospira nuda Waterhouse, fig. 1A,7,8.

Material: eight specimens; 2 almost complete internal and external moulds, 4 partial external moulds of the spire regions (one a very small fragment) and 2 partial external moulds of adapertural whorls.

Description: large helicocone (maximum diameter 33mm), moderately high (maximum height 24mm), trochiform to turbiniform with rapidly expanding whorls, 5-6 in mature specimen; protoconch and apical 2 whorls planispiral, with translation down the spire axis commencing at about the 3rd whorl; by halfway around the 4th whorl, overlap reaches the base of the selenizone and whorl profile has assumed the mature configuration. Mean spire angle of mature specimens is about 100° (tangential to the adapertural whorls).

Mature whorl profile consists of a nearly flat sutural shelf, a strongly rounded sutural carina and a high, concave outer face sloping at about 25° to the spire axis, towards a sharply rounded to angular peripheral carina; a narrow concave band separates this from a prominent cord at the outer edge of the base; the outer base is gently convex to a rounded mid-basal angulation, and the inner base is gently convex, flat or gently concave to the narrow umbilicus.

Growth lines are prosocline across the ramp, gently sinused around the sutural carina and prosocline (about 40° to the spire axis) and gently prosocyrt across the outer face to the periphery. The peripheral carina marks the adapical margin of a broad, shallow (about 2mm deep) slitband and the peribasal cord marks its adapertural margin; growth lines are almost radial across the outer base and slightly prosocline and prosocyrt across the inner base. The columellar lip is thickened and gently curved.

The protoconch is smooth. Regular, lamellate collabral threads occur from the start of the teleoconch to the end of the 3rd whorl; rounded spiral cords, with wide, flat interspaces dominate ornament from halfway around the 4th whorl, although they appear first near the end of the 3rd. The 3rd whorl has about 3 collabral threads per mm on the outer face and the 6th whorl has 8 spiral cords on the ramp, 16 across the outer face, 14 across the outer base and 4 to 5 across the inner base. The selenizone is ornamented by fine, regular, lamellate lunulae on all whorls seen.

Remarks: most of the specimens are better preserved than the holotype and reveal that the species is more strongly ornamented than

previously suspected. Waterhouse (1963a, p.120) distinguished P. nuda from P. fimbriae by its "...wide sutural shoulder and narrow umbilicus, and fainter closely spaced radial threads, and fine spirals.". Because ornament is stronger than in other specimens, and other distinguishing features are variable, the Mantle Volcanics specimens throw some doubt on the differentiation of the two species. Pandospira is unknown outside New Zealand.

Family Eotomariidae Wenz 1938
Subfamily Neilsoniinae Knight 1956
Genus Peruvispira Chronic 1945
Peruvispira robusta Waterhouse
Fig. 11.
1963 Peruvispira robusta Waterhouse p.591, fig.1, 10-15.

Material: 2 half external moulds, one rather weathered.

Description: small (height 3.6mm; maximum diameter 2.8mm), high spired (mean spire angle 60°), anomphalous helicocone with 4 or 5 whorls present; protoconch broken. Whorl profile consists of a concave, steeply sloping (about 50° to the spire axis) upper whorl face to a strong, angular carina at about the upper third of the whorl; a narrow, strongly concave band separates this carina from the peripheral carina near mid-height and another concave zone of similar height separates that from a further, slightly blunter carina; from there, whorl profile is gently convex to the columella.

Faint collabral threads are prosocline (about 40° to the spire axis) and slightly prosocyrt across the upper whorl face to the upper carina which lies at the adapical margin of the selenizone; depth of slit unknown and lunulae defined by faint, regular threads. From the peripheral carina, the adapertural limit of the selenizone, collabral threads are prosocyrt and opisthocline (35° to the spire axis), becoming prosocline near the peribasal carina and remaining so across the base to the columella. Whorl overlap just covers the adapertural carina of the previous whorl. One specimen shows a very faint spiral thread on the base.

Remarks: the small size, strong, concave upper whorl profile, relatively high mean spire angle and strong peribasal carina

distinguish this species from its allies (Waterhouse 1963b). The specimens from D39/f031 are closely comparable with the type material.

Class Bivalvia
Subclass Pteriomorphia Beurlen 1944
Family Eurydesmidae Reed 1932
Eurydesmidae gen. et sp. indet.
Fig. 12, 13.

Material: one right valve internal and nearly complete external mould, one nearly complete right valve internal mould and part of its external and a juvenile double valved internal and external mould with anterior missing.

Description: large (maximum length 93mm), ovate to sub-elongate (maximum height 86mm), thick-shelled, ?equivalve and strongly biconvex; beak situated near anterior third, prosogyrous. From the beak, the dorsal anterior margin is straight or faintly concave, the anteroventral margin rounded with a more gently rounded ventral edge, becoming strongly curved around the posterior to the hinge. Growth lines reveal a gentle anterior gape, this part of the valve being separated from the rest by a low, radial ridge. Maximum inflation is near the dorsal third and slightly behind the beak. Growth lines lamellate near anterior and posterior margins where they are overprinted by growth rugae; weaker concentric striae and increments present over the rest of the shell.

Internally, there is a deep umbonal cavity and the umbo lacks secondary thickening. The pallial line is faint, obscure on the anterior part of the moulds, but clear elsewhere, terminating in a large, kidney-shaped posterior adductor at about half the height of the valve.

The right hinge is characterised by a thickened, rounded anterior margin with growth lamellae, a deep byssal notch beneath the beak and a completely opisthodetic, strongly concave, striated ligament area; no resilifer present; the anterior end of the ligament area is bounded by a strong fold extending posteriorly and ventrally from the beak to the hingeline; this fold forms the byssal notch.

Remarks: the specimens display some characteristic features of the genus Eurydesma, including the large size, inflated ovate shape, thick shell, large posterior adductor scar, entire pallial line, nature of the right valve hinge and ornament. However, they also show some features atypical of the genus. These include the anterior gape, the slightly elongate shape and low anterior radial ridge, lack of umbonal thickening and lack of a large socket on the right valve. E. subdepressa Sahni and Srivastava (1956) appears to be reasonably close in shape, though hinge details are not clear for that species. E. cordatum Morris and E. playfordi Dickins (see Dickins 1957; Runnegar 1968) differ in having strong hinge teeth and a highly thickened umbo. Further material is needed to prove generic identity.

Family Aviculopectinidae Meek and Hayden 1865
Subfamily Etheripectininae Waterhouse 1982
Genus Etheripecten Waterhouse 1963
Etheripecten cf. tenuicollis (Dana)

1847 Pecten tenuicollis Dana p.160
1849 Pecten tenuicollis Dana, Dana p.705, pl.9, fig.7, 7a.
1906 Aviculopecten tenuicollis (Dana), Etheridge and Dun p.13, pl.13, fig.10-12; pl.14, fig.5.
1982 Etheripecten tenuicollis (Dana), Waterhouse p.16-18, pl.1g, pl.2a-g, pl.3a,d.

Material: a single small fragment, external and internal moulds, of a left valve anterodorsal margin.

Description: valve small (fragment height 10mm, length 10mm), little inflated with an acute angle (about 40°) between the hingeline and the low posterior umbonal wall. Growth lines are fine, regular and well marked across the auricle (particularly dorsally) but only faintly visible on the disc; they show that the ventral margin of the posterior ear forms an acute angle (about 35°) with the hingeline before curving gently across the umbonal wall to the rounded ventral margin, forming a shallow posterior auricular sinus.

The disc is ornamented by high, steeply rounded primary radials with wide interspaces, each with a faint, low secondary rib; there are 9

primary radials on the fragment preserved, the probable total across the whole valve being 12 to 15. Growth lines arch dorsally over the radial costae. The posterior auricle has a shallow radial groove just beneath the hingeline and faint radial ribs below.

Remarks: although it does not possess the subspinose costae and scalariform concentrics described by Waterhouse (1982b; see also Dana 1849; Johnston (for Aviculopecten sprenti) 1888), the lack of these features may be explained by the fact that this specimen is no more than an umbonal fragment which may also be worn; in other characters it matches well with E. tenuicollis (= E. sprenti (Johnston); see Waterhouse 1982b for synonymy).

Family Streblochondriidae Newell 1938
Genus Streblopteria M'Coy 1851
Streblopteria sp.
Fig. 14.

Material: one nearly complete left valve external and the posterior half of its internal; the anterior ventral half of a right valve, internal and external moulds.

Description: moderate size (length 35mm; height 27.5mm), slightly opisthocline, moderately inflated, ovate, with a large anterior and small posterior ear; umbo slightly anterior of mid-length with an obtuse umbonal angle (about 120°) and high anterior and moderately high posterior umbonal slopes; anterior umbonal ridge gently concave, posterior almost straight. Maximum inflation near 1/3rd height beneath the umbo. Hinge length is about half valve length. Ornament consists of very faint concentric lines on the disc and growth lines with one or 2 prominent rugae on the ears. Both anterior and posterior auricular margins are gently concave, forming obtuse angles with the hinge (anterior 110°; posterior 135°). Anterior ear almost twice as long as posterior, the former convex, the latter almost flat; ligament area unknown.

Remarks: the nearly complete left valve shows a concentric arrangement of silicate minerals (?zeolites) after decalcification which probably represents relict crossed lamellar shell structure (cf. Boyd and Newell 1984).

Of the few Australasian members of the genus that have previously been figured, this specimen most closely resembles S. minauris Waterhouse (1987). The rounded valve form, lack of radial ornament, with only very faint concentric ornament, the prominent left anterior auricle and its separation from the disc by a deep channel are features in common. However, the Skippers Range specimen has a broader umbonal angle and completely lacks any byssal notch in the left valve. S. minauris is known only from the Brae Formation of the south-east Bowen Basin, which Waterhouse (1987) tentatively correlates with the lower Letham fauna (immediately pre-Echinalosia maxwelli Zone age; see Table 1).

Waterhouse (1982b, p. 28, pl. 13c) described and figured a left valve as Streblochondria sp. A from the lower Takitimu Group. This specimen may belong to Streblopteria and is the closest New Zealand specimen to the Mantle volcanics form.

The Mantle Volcanics specimen differs from other species in its rounded shape and in completely lacking radial ornament.

Family Deltopectinidae Dickins 1957
Genus Squamuliferipecten Waterhouse 1986
Squamuliferipecten cf. squamuliferus (Morris)
Fig. 15.
1845 Pecten squamuliferus Morris (in Strzelecki), p.278, pl.14, fig.1.
1906 Aviculopecten squamuliferus (Morris) Etheridge and Dun, p.8, pl.1, fig.4; pl.2, fig.4,5; pl.8, fig.4.
1929 Aviculopecten squamuliferus (Morris) Fletcher, p.4-6.
1982 Corrugopecten squamuliferus (Morris), Waterhouse, p.38.
1986 Corrugopecten (Squamuliferipecten) squamuliferus (Morris) Waterhouse, p.6.
1987 Squamuliferipecten squamuliferus (Morris) Waterhouse, p. 157, pl. 7, fig. 1; pl. 8, fig. 10.

Material: well-preserved umbonal half of a right valve, with both internal and external moulds.

Description: Long anterior ear, the margin of which projects anteriorly (at an angle of 105° to the hingeline) to just below mid

auricular height before rounding to the byssal notch. Growth lines show the disc to be nearly semicircular although slightly prosocline. Posterior ear subtriangular, forming an acute angle (about 70°) with the hingeline, and almost as large as the anterior ear. The umbonal angle is close to 90° and posterior umbonal ridge high, probably largely owing to post mortem distortion of a moderately inflated valve. About 30 high, rounded primary radial costae on the disc and a further 7 on the anterior ear and 8 on the posterior; secondaries are intercalated in some interspaces, particularly near the broken ventral disc extremities, and on the posterior ear. Regular concentric lamellae, 12 per 10mm, cross the costae without deflection and continue across both ears, forming low blades and spines on the costae, particularly on the anterior ear. The posterior interarea and part of a broad, shallow, central subumbonal resilifer are visible on a latex cast.

Remarks: Waterhouse (1982b) erected Corrugopecten (based on a new species C. altoprimus), then erected Squamuliferipecten (based on type species Aviculopecten extensus Fletcher, 1929) in 1986 as a new sub-genus of his Corrugopecten, elevating it to full generic status in 1987. While in this paper we follow the most recent nomenclature, we remain unconvinced of its validity.

Squamuliferipecten extensus (Fletcher) is higher than long and and has less clearly defined concentric lamellae than this specimen.

Squamuliferipecten squamuliferus (Morris) differs from Corrugopecten multicostatus in having a large, costate posterior ear (Morris 1845), only occasional intercalated secondaries between primary costae, more rounded costae and more marked frilly concentric lamellation.

Genus Corrugopecten Waterhouse 1982
Corrugopecten cf. multicostatus (Fletcher)
Fig. 16.

1929 Aviculopecten multicostatus Fletcher, p8-9, pl. 2, fig. 1-3
1982 Corrugopecten cf. multicostatus Waterhouse p.38, pl. 20 a-e.

Material: 2 slightly corroded partial external moulds, one a large part of the anterior of a right valve disc and ventral part of the

anterior ear, the other a fragment of ventral margin.

Description: Right valve nearly flat, 73mm high and 60mm long from close to the anterior margin to near mid-disc. Anterior ear long and rounded to its ventral margin, with a very deep byssal notch and a long straight disc margin below; from the anterior edge of the disc, the margin, judging from growth lines, is evenly rounded to the ventral extremity of the valve. Ornament dominated by 14 high, sharply rounded primary radials with deep, rounded inter-costae; costal flanks flat in profile. One, 2 or 3 secondary costae intercalated between some primaries, at least one in most primary interspaces except for four at the anterior margin. Regular growth lamellae (about 1 per mm) and radial ornament reticulate, forming dorsally deflected scales on the costae, ventrally deflected between; two concentric growth rugae on the preserved part of the disc. Anterior ear similarly ornamented, though without secondary costae and with more prominent concentric lamellae, forming a strong crenulation over the 5 radials present.

Remarks: these specimens are distinguishable from Squamuliferipecten cf. squamuliferus by the multiple secondary costae, flat-sided primaries, less well developed concentric lamellae and low inflation. Ornament is similar to the specimens attributed to C. cf. multicostatus from the Notostrophia homeri Zone of the Takitimu Group by Waterhouse (1982b). Neither the Takitimu nor the Mantle Volcanics specimens have posterior ears preserved, so positive identification cannot be made.

Phylum Echinodermata
Class Crinoidea Miller 1821

Material: Moulds of several types of crinoid columnal ossicles are found in the collection, but no attempt at identification of most has been made.

Calceospongia sp.

Material: A partly dissociated calyx with brachial arms still articulated.

Description: The calyx has subpentagonal basals and radials which give rise to perforate brachial ossicles. Brachials divaricating, tapering with ossicles about as wide as long, and sub-circular in cross section.

Class Echinoidea
Order Cidaroida Claus 1880
?Family Archaeocidaridae McCoy 1844
?Archaeocidaridae gen. et sp. indet.

Material: Three ?archaeocidarid adambulacral plates and a number of spines.

Description: Each plate has a single, raised, sub-central, perforate, non-crenulate boss; two specimens show a round, differentiated aureole, nowhere reaching the margin; each aureole is surrounded by scrobicular zones. The tubercle is located on a low platform, with a well defined parapet. Plates are thickest near the middle, and taper gently to the margins.

Spines are thin (1.5mm diameter), elongate and gently tapering with very fine longitudinal striation.

Age:
Notostrophia zealandicus/homeri Zone (Waterhouse 1973b); Telfordian Stage (Waterhouse 1965, 1967), Fauna IIIA (of Dickins 1964), Ingelarella ovata/plana/plica Zone (of Waterhouse and Jell 1983), ?Wyndhamia brittoni Zone (of Waterhouse and Jell 1983).

Correlation:

National: Waterhouse (1958;1963a;1963b;1964;1968;1973a;1982a; 1982b) has described faunas from the Telfordian Stage which include Notostrophia zealandicus, N. homeri, ?Lissochonetes sp., Terrakea pollex aurispina, Ingelarella sp. (listed as Ambikella ovata; see Waterhouse 1983), Notospirifer aff. hillae, Etheripecten tenuicollis, Deltopecten aff. limaeformis, and Corrugopecten cf. multicostatus. Using these faunas, he defined (1973b) two brachiopod zones based (in ascending order) on the occurrence of Notostrophia zealandicus and N.

homeri. These zones are found in stratigraphic succession in a section along the Wairaki River, Takitimu Mountains, within the Brunel Formation (Houghton 1981).

The occurrence of a specimen compared with the restricted zone fossil, Notostrophia homeri, in the Mantle Volcanics fauna suggests correlation with the upper part of the Telfordian Stage of the Takitimu Mountains. The correlation is supported by the occurrences of Pandospira nuda, Peruvispira robusta and Notospirifer sp. (cf. sp. A of Waterhouse 1982a). In addition, several genera in the Mantle Volcanics fauna are found within the N. homeri Zone and are represented by specimens too poorly preserved to show definite species relationships.

Fossils from the Gondor Formation (Plato terrane) in the Eglinton Valley area (Waterhouse et al. 1983) include some forms represented in the Mantle Volcanics Formation, including the genera Etheripecten, Pandospira and Aperispirifer.

By comparing it with the Australian Bowen Basin faunal succession Waterhouse et al. (1983) concluded that the Gondor fauna is slightly older than the Notostrophia zealandicus Zone of the Takitimu Mountains and is the oldest Permian fauna yet found in New Zealand; the Takitimu Notostrophia zealandicus fauna is succeeded by the Takitimu N. homeri fauna.

Owing to difficulties in differentiating their indicator species or any other element of their faunas. As we accept the relative ages of these two zones (and that of the Gondor fauna), we have accommodated this uncertainty by correlating the Mantle Volcanics fauna with both zones. This work throws some doubt on the separability of the N. zealandicus and N. homeri zones.

International: in Table 1, important Early Permian fossil occurrences in Queensland, New South Wales, Tasmania and New Zealand are standardised about the Ingelarella zones of Runnegar and McClung (1975) and McClung (1978). The Ingelarella species succession is valuable for correlation in this part of the Early Permian and is based on sequences in the northern Sydney Basin (I. elongata, I.

koninckí) and the Back Creek Group near Holmvale Station in the northeast Bowen Basin, Queensland (I. ovata, I. plana). Waterhouse (in Waterhouse and Jell 1983) recognised I. elongata and I. plana for the first time in the Bowen Basin and proposed modifications to the zonal sequence, confining I. ovata, I. plana and I. plica to a single zone, the ovata/plana/plica Zone. The specimen from the Mantle Volcanics described here as I. cf. plana, is similar, but not identical to I. plana.

A parallel zonal subdivision using Wyndhamia species was also established by Runnegar and McClung (1975). This scheme has also been modified (Waterhouse, in Waterhouse and Jell 1983) to include species of Strophalosia and Echinalosia. In their scheme, Waterhouse and Jell (1983; p.244) indicated that the Ingelarella ovata/plana/plica Zone is represented by three Echinalosia and Wyndhamia zones, E. n. sp., W. brittoni and E. preovalis in stratigraphic succession. Occurrence of Wyndhamia ingelarensis in eastern Australia is restricted to the Aldebaran, Ingelara and Catherine formations in the Bowen Basin (Dear 1971) and to the Cascades Group in Tasmania (Clarke 1969). Because the Mantle Volcanics specimen differs from the descriptions of W. ingelarensis, correlation with these stratigraphic levels is rejected in favour of other consistent data.

Lissochonetes specimens from the Mantle Volcanics are here compared to the Australian species L. yarrolensis, known from occurrences in Queensland's Bowen and Yarrol Basins. It is found in: the Sirius Shale (Dear 1972); the middle part of the Tiverton Formation of Holmvale (Waterhouse 1983); Buffel Formation of the southeast Bowen Basin; and its type locality in the Yarrol Limestone of the Yarrol Basin (Maxwell 1964). Each occurrence is consistent with an ovata/plana/plica Zone age. Waterhouse (1964) described and figured a single pedicle valve of a chonetid (gen. et sp. indet; p.27, pl. 4, fig. 1,2) from the Telfordian Stage (Notostrophia zealandicus Zone) of the Takitimu Group; that specimen does not belong to the same species as the Mantle Volcanics form, which is small and characteristically up to 2 times wider than long.

Waterhouse (1983) based his species Aperispirifer crassicostatus on specimens from the N. zealandicus and N. homeri zones of the Takitimu

Group and included specimens from the upper Tiverton Formation (near Exmoor Homestead, Queensland) within the species. Again, this occurrence is consistent with an ovata/plana/plica Zone age.

Etheripecten tenuicollis (Dana) was erected for specimens collected from Allandale Formation rocks of Harpers Hill (Sydney Basin), and Australian occurrences were summarised by Waterhouse (1982b). The species ranges as high as the Farley Formation (see Table 1) of the Sydney Basin and is known also from Tasmania. Farley Formation is largely ovata/plana/plica Zone in age.

Little is known about the occurrence of Squamuliferipecten squamuliferus (Morris); it was originally described from "Mount Wellington (Van Dieman's Land)" (Morris 1845; probably Berriedale Limestone; Ingelarella ovata Zone). Fletcher (1929) added "Farley, Ravensfield, Pokolbin (New South Wales)" (all Farley Formation; Ingelarella konincki-ovata zones) and "Huon Road (Tasmania)" (zone uncertain) to the list of localities.

In summary, evidence points to correlation of the Mantle Volcanics fauna with the Ingelarella ovata/plana/plica Zone. Probable Australian correlatives are faunas from the Sirius Shale, upper Tiverton, upper Farley formations and perhaps Buffel, Yarrol and Berriedale formation faunas.

Biological and Ecological aspects

The Mantle Volcanics fauna is essentially a post mortem accumulation, but double valved specimens of Lissochonetes cf. yarrolensis, Plekonella sp. indet., Notospirifer sp. and the eurydesmid, as well as the articulated crinoid show that some specimens were alive (or not long dead) at the time of burial.

Bryozoan colonies on the externals of Notostrophia cf. homeri, Ingelarella cf. plana, the eurydesmid and Streblopteria sp. may have attached during life; however, those attached to the internal moulds of the eurydesmid, Notostrophia cf. homeri and possibly Streblopteria sp. show conclusively that some shells lay unburied for some time after death.

Runnegar and Campbell (1976) list many Australian occurrences of Permian genera within inferred environmental situations. Groups listed under the category "shallow shelf (near wavebase) sands and silts" include Eurydesma, Aviculopecten, Deltopecten, Martiniopsis (here Ingelarella), Trigonotreta, Wyndhamia, gastropods, bryozoa, solitary rugosans and echinoderms. The faunal assemblage from D39/f031 fits well into this grouping.

Runnegar (1979) listed Eurydesma, Deltopecten, and Aviculopecten from rocky shoreline, Deltopecten, Peruvispira and Ingelarella from a proximal sandy shoreface and Deltopecten, Ingelarella, Trigonotreta and fenestrate and ramose bryozoans from distal sandy shoreface environments. He established that many East Australian Eurydesma localities are nearshore and/or rocky shoreline facies that had hard, clean substrates at the time of deposition. His interpretation is consistent with that of Dickins (1957, p.16-17). Both authors concluded that Eurydesma inhabited cold to very cold waters; Runnegar goes further and suggests that Eurydesma extinction was caused by rising seawater temperatures.

Waterhouse (1982b) extrapolated from Fleming's (1957, p.12) observation that the living genus Pecten prefers firm, mud-free substrates, inferring that other members of the Pectinacea (Etheripecten, and, by inference, Squamuliferipecten and Corrugopecten), preferred similar conditions. In addition, from the nature of their ornaments he concluded that Etheripecten tenuicollis may have been a poor swimmer and that Corrugopecten (and, by inference, Squamuliferipecten) species may have been attached throughout life.

Waterhouse (1973b) postulated that Notostrophia Zone communities lived "...near a rocky volcanic shore in a highly disturbed environment." This interpretation is supported by the Mantle Volcanics fauna where there are no brachiopods of the "propper" mode of attachment and further by the high degree of rounding of clasts in the conglomerates and breccias, a feature which may have been produced in a beach environment.

The presence of encrusting stenoporids on shells indicates at least moderate energy living conditions. Paleontological data, including

the many complete fenestellid and stenoporid bryozoan colonies and the large, articulated crinoid preserved intact in the assemblage suggest that no violent post mortem depositional events occurred.

Paleontological and sedimentological conclusions on environment of deposition differ in that sedimentological evidence suggests that most of the succession, including the fossiliferous part, was secondarily deposited by submarine debris flow and turbidity current mechanisms with some residual traction current modification. Some paleontological evidence (see above) suggests that re-deposition (of some specimens, at least) is unlikely.

Regardless of these technical inconsistencies, we conclude that the sediments and their associated fauna indicate deposition near an emergent volcanic landmass which resulted in generation of turbidity currents and submarine debris flows. Roundstone conglomerates and the faunal assemblage are indicative of shallow water and/or derivation from areas of shallow water.

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CAPTIONS

Figure 1: Generalised geological map of the Skippers Range area showing distribution of major rock units and fossil locality.

Figure 2-16: all photos are accompanied by a 5 mm scale bar.

Figure 2: Notostrophia cf. homeri Waterhouse. Latex of broken pedicle external mould showing partial encrustation with stenoporid bryozoan.

Figure 3: Notostrophia cf. homeri Waterhouse. Broken pedicle internal mound. Note marginal crenulation, bryozoan attachment point (arrowed).

Figure 4: Lissochonetes cf. yarrolensis Maxwell. Internal mould of pedicle valve.

Figure 5: Wyndhamia sp. aff. ingelarensis Dear. SEM image of latex of broken brachial valve external. Note smooth, convex immature and concave mature form.

Figure 6: Wyndhamia sp. aff. ingelarensis Dear. SEM image of latex of broken brachial valve internal.

Figure 7: Aperispirifer crassicostatus Waterhouse? Latex of broken juvenile brachial valve external.

Figure 8: Ingelarella cf. plana Campbell. Internal mould of pedicle valve.

Figure 9: Pandospira nuda Waterhouse. Latex of mature helicocone external mould, apical view.

Figure 10: Pandospira nuda Waterhouse. Latex of mature helicocone external mould, lateral view. Note planispiral protoconch.

Figure 11: Peruvispira robusta Waterhouse. Lateral view, latex of external mould.

Figure 12: Eurydesmidae gen. et sp. indet. Right valve, internal mould. Note bryozoan attachment scars (arrowed).

Figure 13: Eurydesmidae gen. et. sp. indet. Latex of right valve external mould. Note radial anterior ridge (arrowed).

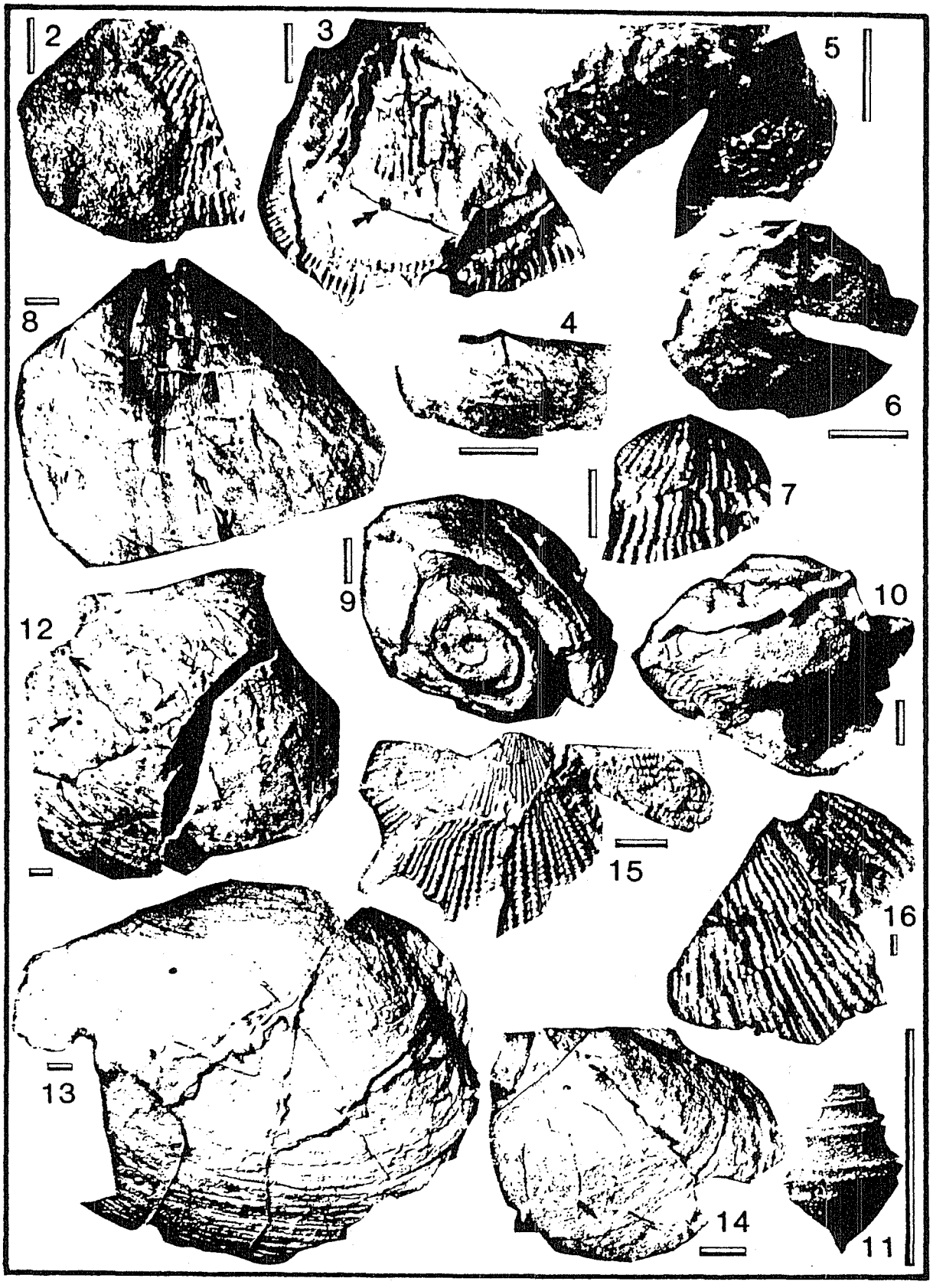
Figure 14: Streblopteria sp. Latex of left valve external mould. Note large anterior ear, small posterior ear.

Figure 15: Squamuliferipecten cf. squamuliferus (Morris). Latex of right valve external mould. Note large, costate posterior ear and rounded, intercalating costae with reticulating concentric lamellae.

Figure 16: Corrugopecten cf. multicostatus (Fletcher). Latex of right valve external mould fragment. Note flat-sided primary costal with many multiple secondary costal intercalated.

Table 1: Important Early Permian stratigraphic sequences and their fossils in Queensland, New South Wales, Tasmania and New Zealand, showing approximate Permian faunal sub-divisions (of Dickins 1964), the Ingelarella zonal scheme of Runnegar and McClung (1975, with modifications after Waterhouse and Jell 1983) and the Echinalosia, Wyndhamia and Strophalosia zonal scheme of Runnegar and McClung (1975, also with modifications after Waterhouse and Jell 1983). Australian occurrences and correlations have been compiled from relevant literature.

NB A refined stratigraphy and biostratigraphy of the south-east Bowen Basin by Waterhouse (1987) has not been incorporated here as we are uncertain of the formality of stratigraphic units.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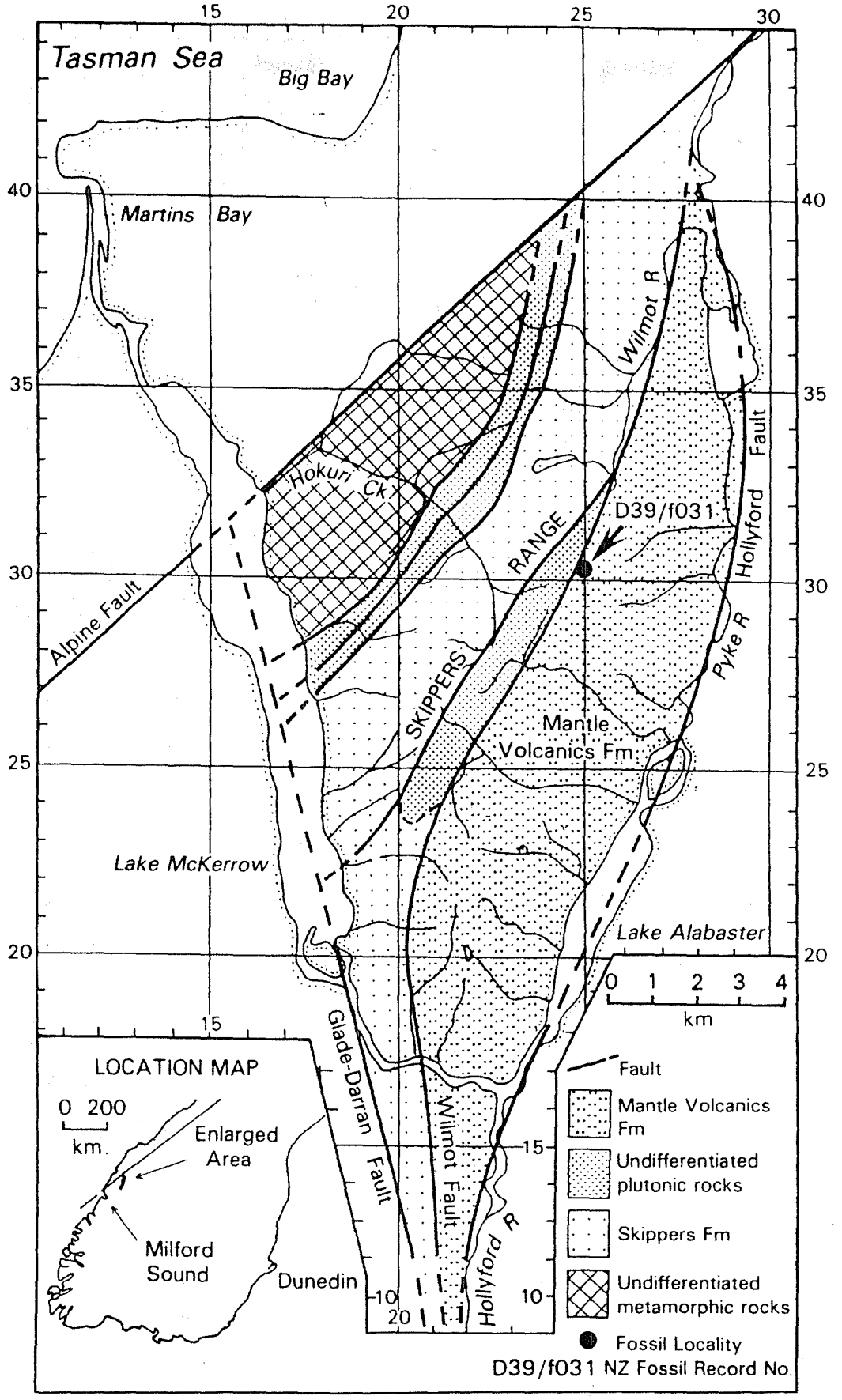
Tasman Sea
Big Bay
Martins Bay
Hokuri Ck
Alpine Fault
SKIPPERS
RANGE
Wilmot R
Hollyford Fault
Pyke R
D39/f031
Mantle Volcanics Fm
Lake McKerrow
Lake Alabaster
0 1 2 3 4
km
LOCATION MAP
0 200
km.
Enlarged Area
Milford Sound
Dunedin
Glade-Darran Fault
Wilmot Fault
Hollyford R
Fault
Mantle Volcanics Fm
Undifferentiated plutonic rocks
Skippers Fm
Undifferentiated metamorphic rocks
Fossil Locality
D39/f031 NZ Fossil Record No.

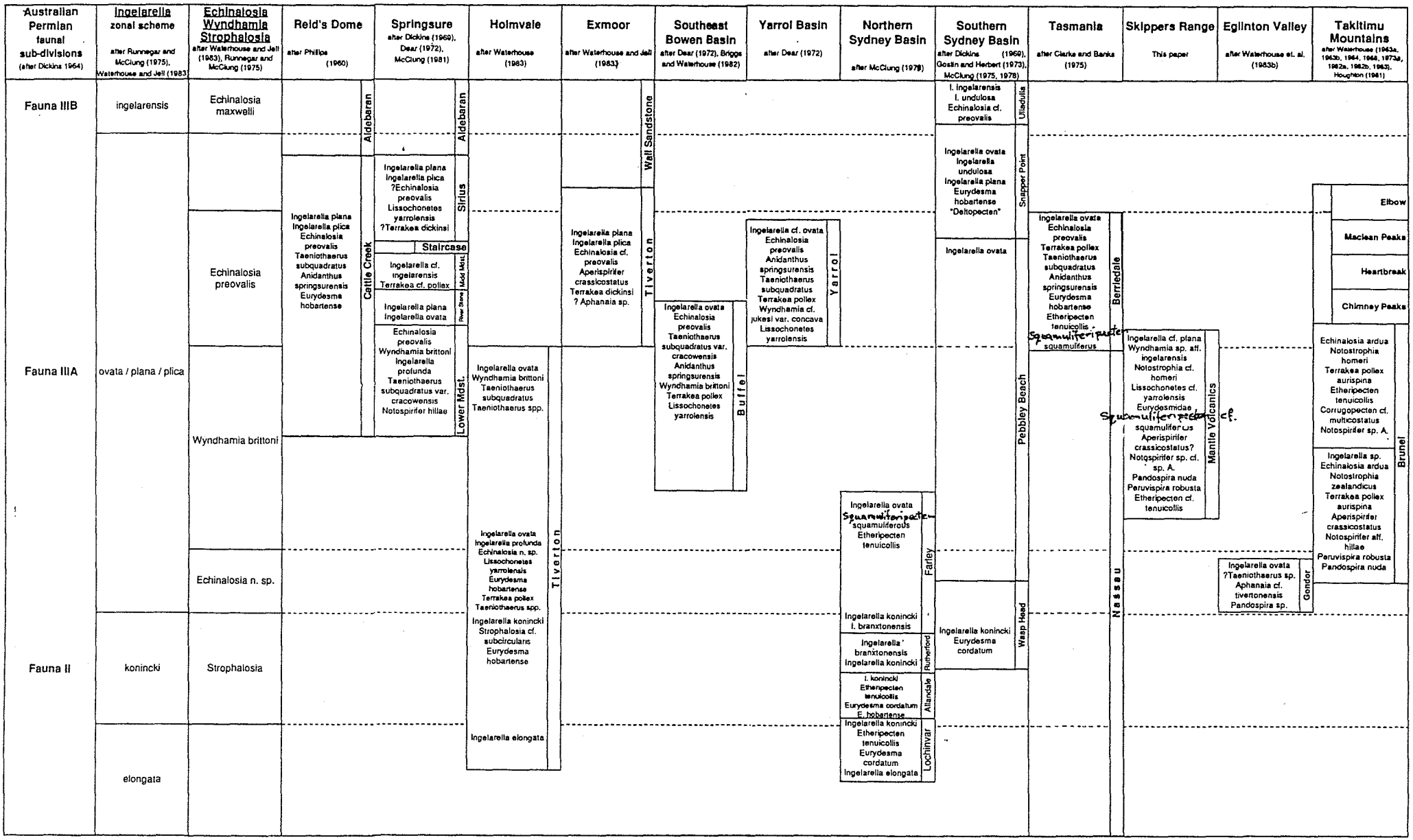
Australian Permian faunal sub-divisions (after Dickins 1964)
Ingelarella zonal scheme (after Runnegar and McClung (1975), Waterhouse and Jell (1983)
Echinalosia Wyndhamia Strophalosia (after Waterhouse and Jell (1983), Runnegar and McClung (1975)
Reid's Dome (after Philips (1960)
Springsure (after Dickins (1969), Dear (1972), McClung (1981)
Holmvale (after Waterhouse (1983)
Exmoor (after Waterhouse and Jell (1983)
Southeast Bowen Basin (after Dear (1972), Briggs and Waterhouse (1982)
Yarrol Basin (after Dear (1972)
Northern Sydney Basin (after McClung (1978)
Southern Sydney Basin (after Dickins (1969), Gostin and Herbert (1973), McClung (1975, 1978)
Tasmania (after Clarke and Banks (1975)
Skippers Range (This paper)
Eglinton Valley (after Waterhouse et. al. (1983b)
Takitimu Mountains (after Waterhouse (1963a, 1963b, 1964, 1968, 1973a, 1982a, 1982b, 1983), Houghton (1981)
Fauna IIIB
Fauna IIIA
Fauna II
ingelarensis
ovata / plana / plica
konincki
elongata
Echinalosia maxwelli
Echinalosia preovalis
Wyndhamia brittoni
Echinalosia n. sp.
Strophalosia
Aldebaran
Cattle Creek
Sirius
Staircase
Madd Mdst.
River Stone
Lower Mdst.
Wall Sandstone
Tiverton
Buffel
Yarrol
Farley
Rutherford
Allandale
Lochinvar
Uliadulia
Snapper Point
Pebbley Beach
Wasp Head
Berriedale
Nassau
Mantle Volcanics
Gondor
Brunel
Elbow
Maclean Peaks
Heartbreak
Chimney Peaks
Ingelarella plana
Ingelarella plica
Echinalosia preovalis
Taeniothaerus subquadratus
Anidanthus springsurensis
Eurydesma hobartense
?Echinalosia preovalis
Lissochonetes yarrolensis
?Terrakea dickinsi
Ingelarella ingelarensis
Terrakea cf. pollex
Ingelarella ovata
Echinalosia preovalis
Wyndhamia brittoni
Ingelarella profunda
Taeniothaerus subquadratus var. cracowensis
Notospirifer hillae
Ingelarella cf. ovata
Anidanthus springsurensis
Wyndhamia cf. jukesi var. concava
Lissochonetes yarrolensis
Ingelarella ovata
Taeniothaerus subquadratus var. cracowensis
Terrakea pollex
Ingelarella spp.
Ingelarella profunda
Echinalosia n. sp.
Eurydesma hobartense
Strophalosia cf. subcircularis
Ingelarella konincki
Ingelarella elongata
Aphanaia sp.
Terrakea dickinsi
Ingelarella ' branxtonensis
Ingelarella konincki
I. konincki
Etheripecten tenuicollis
Eurydesma cordatum
E. hobartense
Etheripecten tenuicollis
Ingelarella ovata
Ingelarella undulosa
Ingelarella plana
Eurydesma hobartense
"Deltopecten"
Ingelarella ovata
Ingelarella konincki
Eurydesma cordatum
Terrakea pollex
Taeniothaerus subquadratus
Anidanthus springsurensis
Eurydesma hobartense
Etheripecten tenuicollis
Squamuliferipecten squamuliferus
Ingelarella cf. plana
Wyndhamia sp. aff. ingelarensis
Notostrophia cf. homeri
Lissochonetes cf. yarrolensis
Eurydesmidae
Aperispirifer crassicostatus?
Notospirifer sp. cf. sp. A.
Pandospira nuda
Peruvispira robusta
Etheripecten cf. tenuicollis
Ingelarella ovata
?Taeniothaerus sp.
Aphanaia cf. tivertonensis
Pandospira sp.
Ingelarella sp.
Echinalosia ardua
Notostrophia zealandicus
Terrakea pollex aurispina
Aperispirifer crassicostatus
Notospirifer aff. hillae
Peruvispira robusta
Pandospira nuda

TABLE 1

Tholeiitic Arc-ankaramites in the Permian Brook Street Terrane: Possible primary melts?

H.R. Ballard
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The Mantle Volcanics Formation (Skippers Range, NW Otago) of the Brook Street Terrane, is a >1300 m thick (base unexposed) pile of moderately southwest dipping pyroclastic and epiclastic rocks. These have been extensively intruded by dikes and subordinate sills and stocks. The sediments are very-coarse breccias and conglomerates, tuff-breccias and crystal-lithic tuffs with clasts similar to the intrusives. The intrusive rocks are predominantly ankaramites characterised by large chrome diopside megacrysts and phenocrysts and basalt to basaltic andesite in composition. Other phenocrysts are olivine (as pseudomorphs), which commonly have idiomorphic magnesio-chromite inclusions, and lesser plagioclase. Augitic clinopyroxene and plagioclase microlites (An_{55} to An_{86}) make up the mesostasis.

Mineralogic equilibration to sub-greenschist facies metamorphism was achieved only locally and as such, the rocks are geochemically well behaved. Ti/V ratios and normalised hygromagmatophile values clearly indicate an arc-tholeiite parentage. Major and trace element variation diagrams show that the rocks sampled can all be related through fractionation of a parental magma low in Ti and high in Mg and Cr represented by three of the most primitive samples. Olivine compositions (estimated from chromite inclusions) and clinopyroxene compositions (analysed) are in close agreement with values predicted from bulk rock chemistry. These samples, although phenocrystic, may represent mantle derived primary liquid which intruded to high levels in the crust and underwent crystalisation without significant fractionation.

Arc ankaramites in modern settings, either alkaline or tholeiitic, often occur where the subducting slab is shoaling, has topographic highs or major fractures. Coupling of the plates would cause propagation of structural discontinuities into the overriding plate and provide an avenue for ascent of primary melts to high levels in the crust. If this is the case, then the occurrence of voluminous ankaramites in the Mantle Volcanics Fm. and elsewhere in the Brook Street Terrane may provide clues to the overall structure of this complex arc assemblage.

THOLEIITIC ANKARAMITE VOLCANISM IN THE PERMIAN ISLAND-ARC BROOK STREET TERRANE OF NEW ZEALAND.

Hyram R. Ballard

Department of Geology, University of Otago, Dunedin, New Zealand

In northwest Otago, a >1300m thick pile of Permian marine, prehnite-pumpellyite grade, pyroclastic and first-cycle epiclastic sediments are disrupted by dikes, sills, and stocks. These intrusions, which comprise nearly 40% of the total volume of exposed rock, are tholeiitic in nature and characterised by a high proportion of clinopyroxene phenocrysts and megacrysts, are termed ankaramites. The enclosing sediments are clinopyroxene and plagioclase crystal-lithic tuffs and tuff-breccias with strong chemical and petrological affinity to the intrusives. This and local development of peperites indicates nearly coeval ankaramitic eruptives and intrusives.

Phenocrysts of the hypabyssal rocks are olivine (pseudomorphed), clinopyroxene and plagioclase with megacrysts of clinopyroxene and olivine. Ca-poor pyroxene is notably absent. Chromite inclusions within the pseudomorphs imply original co-existing olivine compositions as magnesian as Fo_{90}. Groundmass plagioclase compositions range from An_{86} to An_{55}. Clinopyroxene cores are chrome diopside and depleted in Al, Ti and Fe with respect to the rims.

Bulk rock chemistry indicates that olivine+clinopyroxene precipitation should be the major control in a fractional crystallisation model. The high proportion of euhedral clinopyroxene phenocrysts and megacrysts with large un-zoned cores suggests total equilibrium crystallisation. Cox and Bell (1972) have postulated a mechanism of "compensated crystal settling" for very similar rocks of the New Georgia Group, Solomon Islands. This requires a crystallisation chamber with a large height to width ratio which may be expected in areas of rapid tectonic extension. This extension may be continuous to high levels in the crust and possibly generated by subduction of linear features such as spreading ridges (New Georgia), transform faults (New Hebrides) or rifting during opening of back- or intra-arc basins (East Sunda).

If such control of ankaramite generation and eruption can be shown to be valid in the general case, the occurrence in the Brook Street terrane (and in possible equivalents of the Gympie terrane, Australia) will have significant implications for the Permian tectonics of the Gondwana margin.

Reference: Cox, K.G. and Bell, J.D. 1972: A crystal fractionation model for the basaltic rocks of the New Georgia Group, British Solomon Islands. Contr. Mineral. and Petrol. 37, 1-13.

N.Z. Geological Survey, Record 9.
(1985) pp. 11 -15

THE FIRST Eurydesma FAUNA FROM NEW ZEALAND, ITS CORRELATION AND DEPOSITIONAL ENVIRONMENT

J.G. BEGG
Victoria University, Wellington

H.R. BALLARD
University of Otago, Dunedin

Permian volcaniclastic and intrusive rocks outcrop in the Skippers Range of north-west Otago. These are considered to be lateral stratigraphic equivalents of the Eglinton Volcanics and Takitimu Group to the south and the Brook Street Volcanics to the north (see Grindley 1958: Carmen 1968; Nauman 1973). Williams and Smith (1979) showed the Eglinton Volcanics to consist of two distinct suites; the Plato terrane is characterised by primitive island arc tholeites, the Largs terrane by more evolved andesitic rocks. Nauman (1973) named the Skippers Range rocks, Mantle Volcanics Formation. Ballard (work in progress) considers them lithologically and geochemically similar to the Gondor Formation (Williams 1978) of the Plato terrane.

Sediment mass-transport and deposition was by way of debris flows and associated traction and turbidity currents. Sedimentologic data (Ballard, work in progress) suggest deposition on or near the flanks of an island volcano.

A Permian fauna collected by Ballard and Landis from the Mantle Volcanics Formation contains **Eurydesma.** Previously unreported in New Zealand, **Eurydesma** is a large bivalve found widely in Gondwanan Early Permian faunas and believed characteristic of cool waters.

Other elements in the fauna indicate a correlation with the **Ingelarella ovata/plana/plica** Zone (Runnegar and McClung 1975; McClung 1978; Waterhouse in Waterhouse and Jell 1983) of the Australian Early Permian. The Mantle Volcanics fauna is a correlative of the New Zealand **Notostrophia homeri** Zone of the Takitimu Mountains; it is probably slightly younger than the Gondor Formation (Eglinton Volcanics; Waterhouse, Campbell and Williams 1983) and rocks of the **Notostrophia zealandicus** Zone of the Takitimu Mountains.

The Skippers Range **Ingelarella** species is compared with **I. plana** which is found in the upper Cattle Creek Formation (the Sirius Shale) and the upper Tiverton Formation (of Waterhouse 1983) of the Bowen Basin. **Lissochonetes yarrolensis** is found in the Mantle Volcanics Formation and in the Sirius Shale, the middle Tiverton and Buffel Formations of the Bowen Basin and the Yarrol Limestone of the Yarrol Basin. **Aperispirifer crassicostatus** was described from the **Notostrophia zealandicus** and **N. homeri** Zones of the Takitimu Mountains (Waterhouse 1983), and the species was also recognised from the upper Tiverton Formation (Waterhouse 1983) of the Bowen Basin. The Mantle Volcanics Formation **Etheripecten** specimen is compared with **E. tenuicollis** from the Sydney Basin Allandale and Farley Formations. Three specimens of **Corrugopecten** are compared with **C. squamuliferus** from the Farley Formation and Tasmania ('Mount Wellington' of Morris 1845; 'Huon Road' of Fletcher 1929).

East Australian correlatives thus include the Cattle Creek (particularly Sirius Shale), upper Tiverton and Buffel Formations of the Bowen Basin, the Yarrol Limestone of the Yarrol Basin, the upper Farley and upper Pebbly Beach Formations of the Sydney Basin and possibly the Berriedale Limestone of Tasmania.

Paleobiological interpretations support a near-shore, medium to high energy site of deposition. Double valved specimens of **Eurydesma, Notospirifer, Plekonella, Lissochonetes** and an articulated crinoid calyx suggest that specimens have not been transported far from their life positions. **Eurydesma** is believed to have thrived in shallow water, near-shore marine conditions, for it is rare in shelf sediments interpreted as having accumulated below wavebase (Runnegar and Campbell 1976; Runnegar 1979). The species of **Etheripecten** and **Corrugopecten** present are believed to have been attached, or at least relatively immobile (Waterhouse 1982) and to have preferred sediment relatively free of silt. Stenoporid bryozoans encrust occasional outsized clasts, a feature common in shallow marine conditions, although complete fenestellids and arborescent stenoporids suggest a less than extreme physical environment. Bryozoan attachment scars within **Eurydesma, Notostrophia** and perhaps **Streblochondria** valves indicate that shells lay exposed on the seafloor for some time prior to burial.

In summary, the Mantle Volcanics Formation is thought to have been deposited close to an island volcano and the associated fauna lived in cool, shallow, moderately turbulent marine conditions.

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Reconnaissance geology of Brook Street volcanic rocks adjacent to the southeastern side of the Alpine Fault, New Zealand

H.R. Ballard
Geology Department, University of Otago, Dunedin, New Zealand

The Skippers Range in northwest Otago lies at the junction of the Fiordland complex, the Brook Street-Eglinton plutonic-volcanic group and the Alpine Fault. Four major rock units occur in the Range: the Thurso Formation gneisses, and rocks of the Darran crystalline complex representing the northernmost extent of the Fiordland block; the Skippers Formation green schists and the Eglinton group volcanics, the latter two units fault bounded.

The Skippers Formation is unique to the Range, and was previously considered to be a burial metamorphic equivalent of the Eglinton suite. Severe deformation of the Formation requires a more complex tectonic history than simple tilting of a stratigraphic pile.

Ankaramite rocks crop out extensively within the Eglinton terrane. These are of strongly tholeiitic character both in whole rock and mineral chemistry. Their relatively unevolved nature suggests that, at least in this portion of the terrane, the tectonic situation was such that primitive melts were extruded and/or intruded to upper crustal levels.

APPENDIX 6
PERSONAL COMMUNICATIONS

Kimbrough, D.L. U/Pb zircon results from the Slip Hill Diorite

Luyendyk, B. Paleomagnetic results from Mantle Volcanics Formation samples.

Blattner, P. Oxygen isotope results from various samples from the Skippers Range.

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DEPARTMENT OF GEOLOGICAL SCIENCES — SANTA BARBARA, CALIFORNIA 93106

21 August 1984

Dear Hyram -

G'day mate. How are you - long time no hear nothing from you eh ?? Here (back of page), at long last, are zircon U-Pb ages from your Skippers sample. It looks as though there is slight, but real discordance in this sample. Despite the low U contents there has probably been a small amount of Pb loss that would account for this. This sample is very similar to (though perhaps slightly older than?) the Mistake diorite which someone (Coombs ?) has the data for. I will do common Pb & Sr on these rocks before I get back down there in Dec. so we can better evaluate possible relationships.

Sample	Concentrations		Isotopic Ratios			Ages		
OU49142	$^{206*}Pb$	^{238}U	$^{208}/_{206}$	$^{207}/_{206}$	$^{204}/_{206}$	$^{206*}/_{238}$	$^{207*}/_{235}$	$^{207*}/_{206*}$
Coarse 7100 mesh	7.36	236.0	0.23023	0.075035	0.001654	228.2	228.6	233
Fine	7.38	238.5	0.21774	0.064910	0.000958	226.3	227.2	236

PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION
Cover Page

FOR CONSIDERATION BY NSF ORGANIZATIONAL UNIT (Indicate the most specific unit known, i.e. program, division, etc.)	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? Yes ___ No X ; IF YES, LIST ACRONYM(S):
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☐ REQUESTED AMOUNT ☐ PROPOSED DURATION ☐ REQUESTED STARTING DATE ☐ PROPRIETARY AND PRIVILEGED INFORMATION

PRINCIPAL INVESTIGATOR/ PROJECT DIRECTOR	AUTHORIZED ORGANIZATIONAL REP.	OTHER ENDORSEMENT (optional)
NAME Bruce P. Luyendyk	NAME	NAME Michael Fuller

The Brook Street volcanics have been sampled in the Hollyford and Eglinton Valleys, and also the Skippers Range and the Takitimu Mountains where our major focus has been. The Skippers samples have been processed and the Takitumi rocks are in progress.

In the Hollyford Valley (Figure 5) Jack Y. Bradshaw of Otago University collected samples from the Mistake Diorite (Triassic) and from dikes in the Consolation formation (Permian). The dike samples are magnetically stable but the diorite samples are not. The local attitudes are poorly known, but by correcting for the regional attitude of northeast strike and steep east dip, the dikes are normally magnetized with a steep inclination. In 1986 5 sites in volcaniclastic sediments and intrusive units were obtained in the Eglinton Valley; these samples are unprocessed at this time.

Skippers Range

The Brook Street terrane in the Skippers Range is comprised of a fault-bounded block of lower Permian volcanics. These volcanics are 30% by volume dikes, sills, and small plutons in a matrix of tuffs, tuff breccias and breccias (H. Ballard, personal communication, 1984). The local structure is homoclinal with northwest strike and steep southwest dip. Dikes trend northeast and are close to vertical. The intrusive rocks are ankaramite basalt, olivine basalt and gabbro. Intrusion appears to have occurred into wet sediment. The Skippers Range is presently being studied in detail by H. Ballard of the University of Otago as part of his Ph.D. research.

H. Ballard collected 41 samples in a reconnaissance of 12 dikes and sills and tuffaceous sediments in the Skippers Range. Sampling was done across 11 intrusive contacts. Specimens of crystal tuff within 10 cm of the contacts display an NRM (natural remanent magnetization) 10 times above background and MDF's (median destructive fields) over 200 Oersted. About half of the samples are magnetically unstable and did not yield a characteristic direction. However, 5 sites comprising tuff samples in the baked contact zone gave consistent directions. The preliminary VGP for the sites shows an apparently normal magnetization and a moderately steep inclination (I = -64.8, D = 55.8, alpha 95 = 13.4; Figure 7). The scatter of site directions could be reduced by sampling more baked contact zones. It is significant and encouraging that many unstably magnetized samples track towards the mean of the site directions during demagnetization.

The Permian was a time of reversed polarity of the magnetic field; the PC-R interval from 320 to 250 Ma (Irving and Pullaiah, 1976; Cox, 1982). This fact raises a question whether the Skippers directions, which are normal, are primary or remagnetized. However, Irving and Pullaiah (1976) report three normal events in the early Permian. Two of these are in the Sakmarian. The age of fossils found in the Skippers sediments range from Sakmarian to early Kungurian (H. Ballard, personal communication, 1984). Therefore, the Skippers results cannot be rejected on the basis of being of apparent normal polarity.

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Reference: MS/5/1-PB

18 May 1984

Mr H. Ballard,
Dept of Geology,
University of Otago,
P.O. Box 56,
DUNEDIN.

Dear Hyram,

At last I send you six results on Skippers. I am afraid I cannot localise the painstakingly separated (no doubt) clinopyroxene, but we have been flat out with geothermal work, other work and visitors.

Your data all indicate fairly normal, but close to oceanic values. The ankaramites are surprisingly high. The "magnetite" although highly impure, confirms this and absence of a pyroxene analyses is therefore somewhat mitigated. Are these rocks in any way retrograded, possibly at relatively low temperatures?

I leave you to chew the data further for the time, and will be interested in any conclusions and further plans. You may use the results in any responsible manner you like, but give credit to myself at Inst. of Nuclear Sciences and Geological Survey, DSIR.

Best regards.

Yours sincerely,

Peter

(P. Blattner)

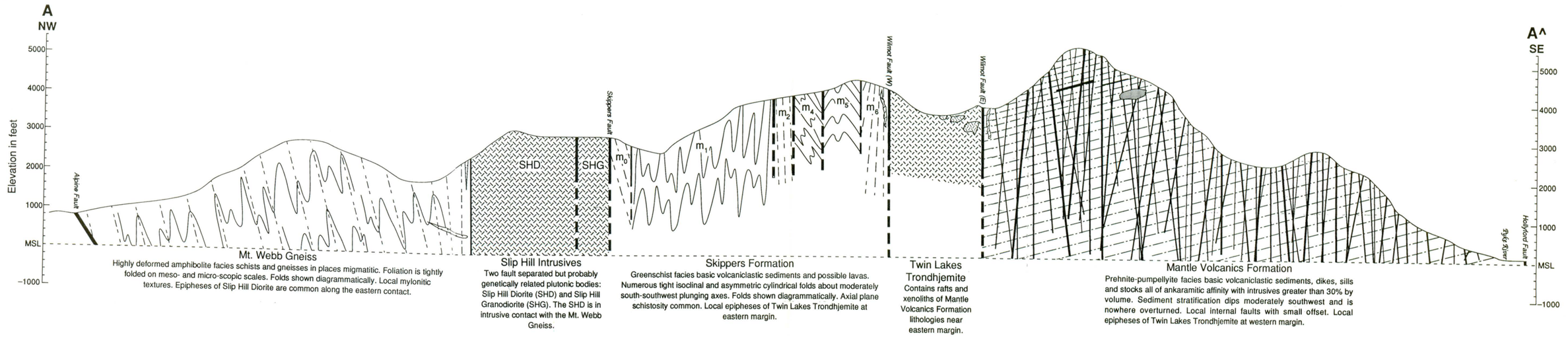
cc Dr G.W. Grindley

Skippers Range (H. Ballard)

IG-8081/---			Co-ord. NZMS 1 Martins Bay S105	‰ $\delta^{18}O_{SMOW}$*	$\frac{\mu moles\ O_2}{mg}$
1	D1	Hornblende quartz diorite	066 444	6.09 ± 0.1 (2)	14.4**
3	Ø2	Hornblende granodiorite	071 448	8.05 ± 0.2 (3)	13.6**
7	35.3.5	Hornblende tonalite	081 469	7.0 ± 0.3 (2)	13.6**
8	Ank 1	Ankaramite	092 412	6.9 ± 0.3 (2)	13.5
12	do.	Separated magnetite		5.5 ± 0.5 (2)	impure !
10	323.2.9	Ankaramite	.....	8.05 ± 0.1 (2)	13.3

* NBS28 9.80‰

** c.10% epidote incompletely reacted



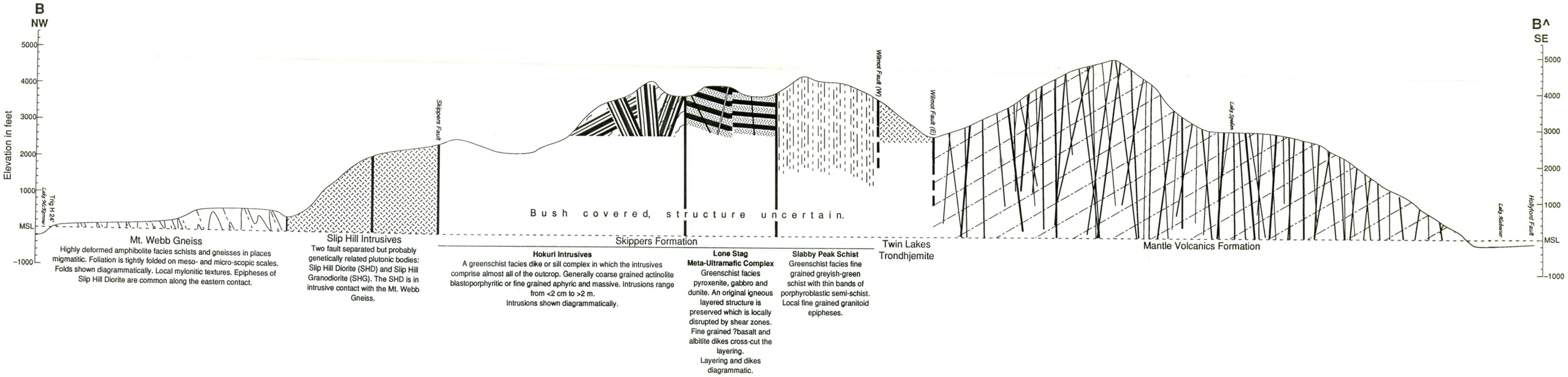


Plate 2P

Cross sections along the lines A–A^ and B–B^ illustrating the geology of the Skippers Range. There is no vertical exaggeration of the topographic profiles. Some small scale features have been exaggerated in size for clarity and folds and dikes are depicted diagrammatically. Confidence levels are based on altitude limits of mapped contacts or exposed structure.

Measured Lithologic Section, Northern Skippers Range, N.Z.

Depicting physical characteristics, intrusive relations, and bulk chemistry.

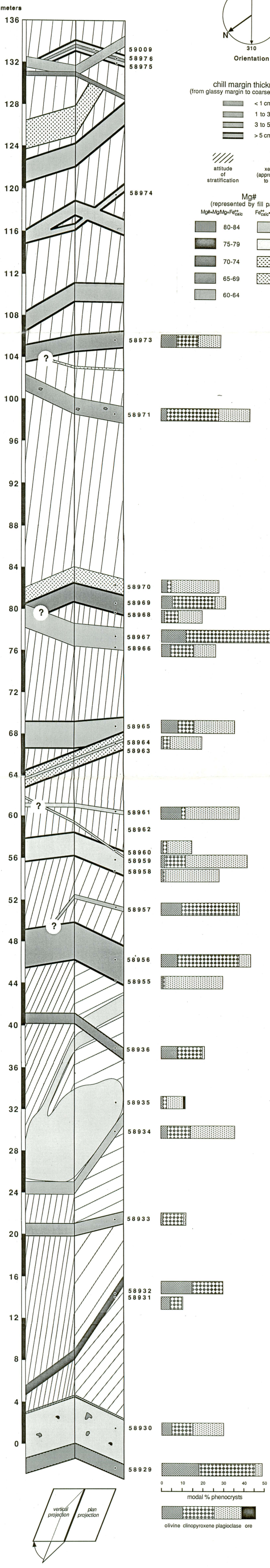


PLATE 1P. This is an example of one of the lithologic sections measured in the Mantle Volcanics Formation and shows the extent of intrusive activity which is characteristic of the Formation. Note that the section is composed of two columns divided by a folding line. The column on the right is the measured plan view and the column on the left a vertical projection perpendicular to the average strike of the dikes. A predominant feature of many of the dikes is a fine grained plagioclase phyric margin of varying thickness grading rapidly to a coarse grained olivine, clinopyroxene and plagioclase rich phenocrystic to megacrystic core.

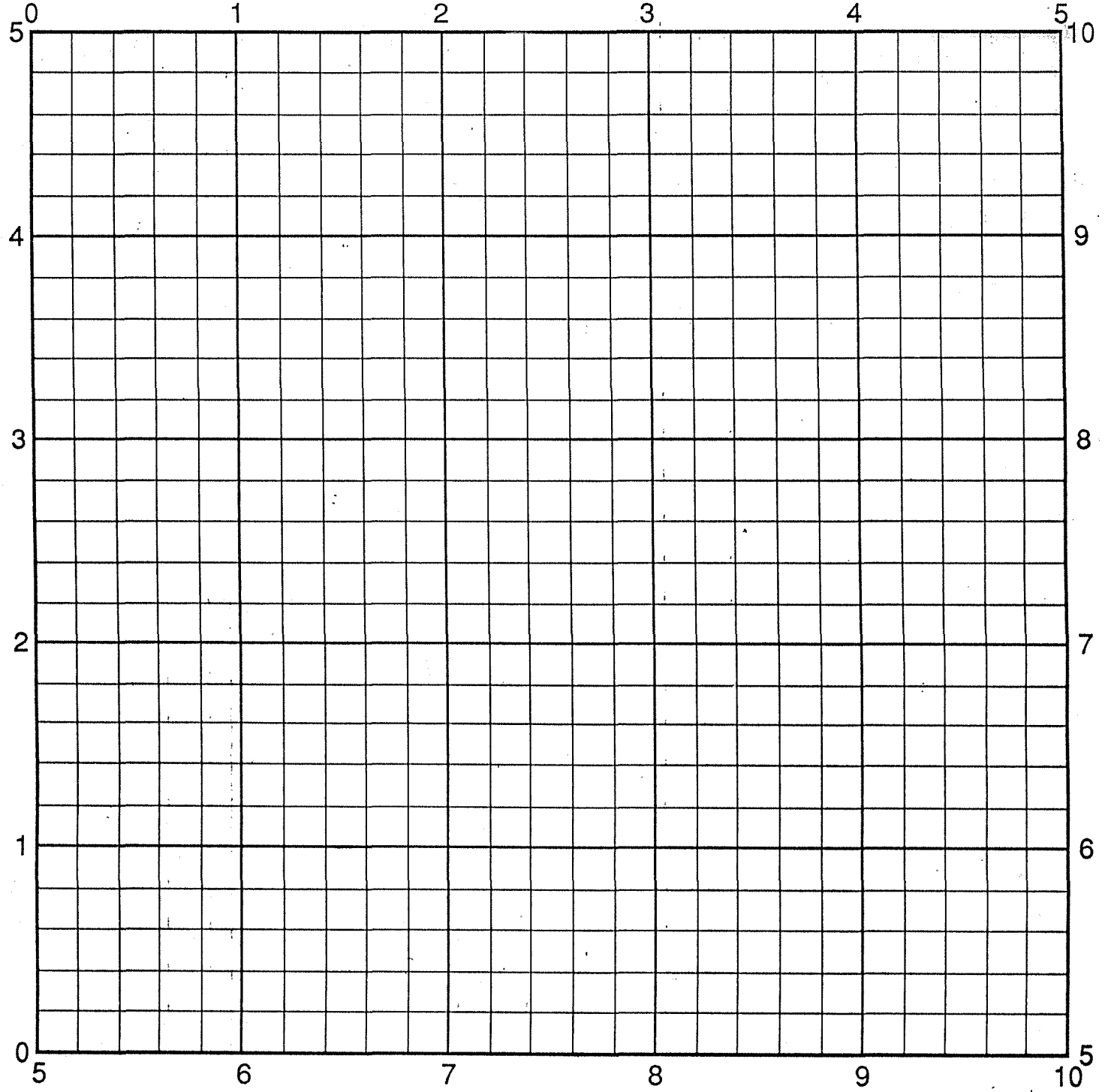


Plate 3P

1000 Yard Grid Overlay
1:25 000

To find a grid reference:
Place a corner of the overlay on a grid line intersection and count along the appropriate edge. Fine divisions are 200 yards.